Cécile Morillon

Huanglongbing
the citrus disease

You've lost, Francis!

And with that, I ran out of orange juice! Can you go get some, Mum?

Ho! You're very demanding! Do you know that one day there might not be any orange juice left on the planet?

No way!

Yes. Citrus trees are sick. They're victims of the yellow dragon, a deadly bacterial disease.

Whoa! A draaagon!

It's just an expression, Francis. The Chinese call this disease the "Huang-Long-Bing"...

... or HLB*! It means "yellow dragon disease"!

This disease has been known in China since the end of the 19th century. A small insect that infects trees when it feeds on the leaflets.

Wow!

Citrus culture area

Citrus culture area

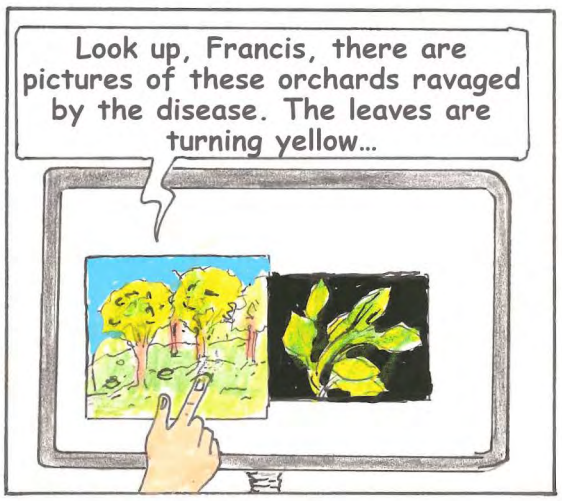
Look at the extent of the disease, in yellow.

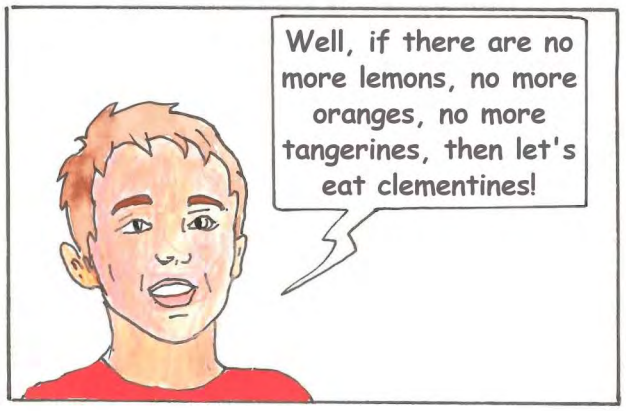
In Brazil, the main producer of orange juice, production fell by almost 20%. In Florida and the United States, almost 70% of citrus orchards have been devastated.

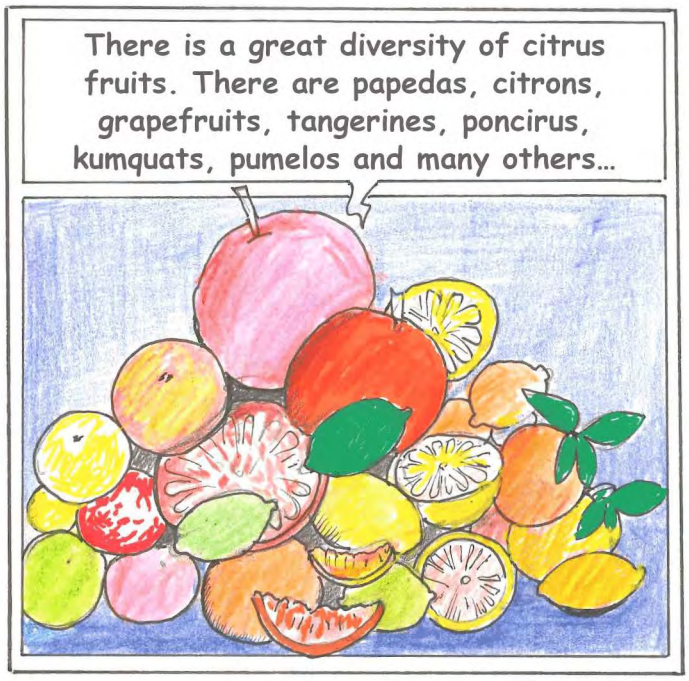
French Polynesia, Australia, New Zealand, Western Asia and the Mediterranean basin are not affected yet.

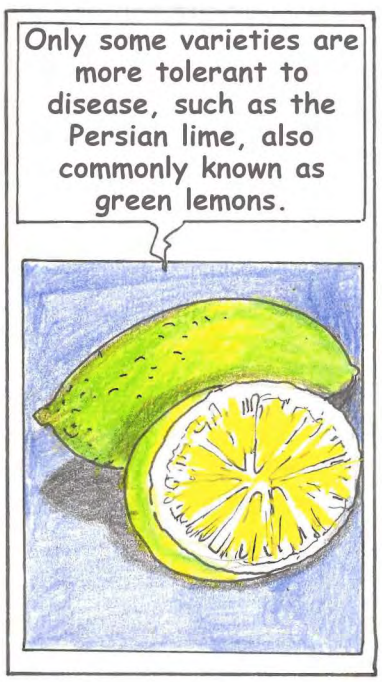
*also known as citrus greening in English or 黃龍病 in Chinese.

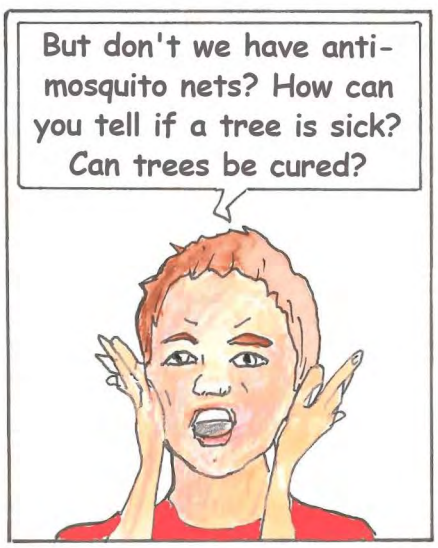
In Guadeloupe, citrus fruit productions dropped by 70% because of the HLB.











*"It's very hot!" in Guadeloupean Creole.

The disease develops in one or two years, and the tree may die five years after being infected with the bacteria.

What about the fruit? Is it poisoning?

No, not really...

... but the fruit has a terribly bitter taste... It doesn't look pretty...

... and it has more skin than pulp!

Yuck, disgusting!

As soon as the fruit and leaves turn yellow,...

... it's a sign that the tree is sick?

Yes. But they say it's already too late... The bacteria are spreading from the leaves to the roots...

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The citrus greening di

... and then throughout the tree. The yellowing of the leaves...

... only appears later and is due to an overreaction of the tree!

You mean that the tree is trying to protect itself from the bacteria?

It's a bit complicated! Here some explanations are given on this insect vector and on the tree's response to the bacterium.

YouTube

Citrus in danger

I'll leave you with Professor Plonk. In the meantime, I'm going to see if there's any juice left at the supermarket!

Pay attention!

Hello Francis, I'll explain to you what this insect is and how it infects the trees. Here it is...

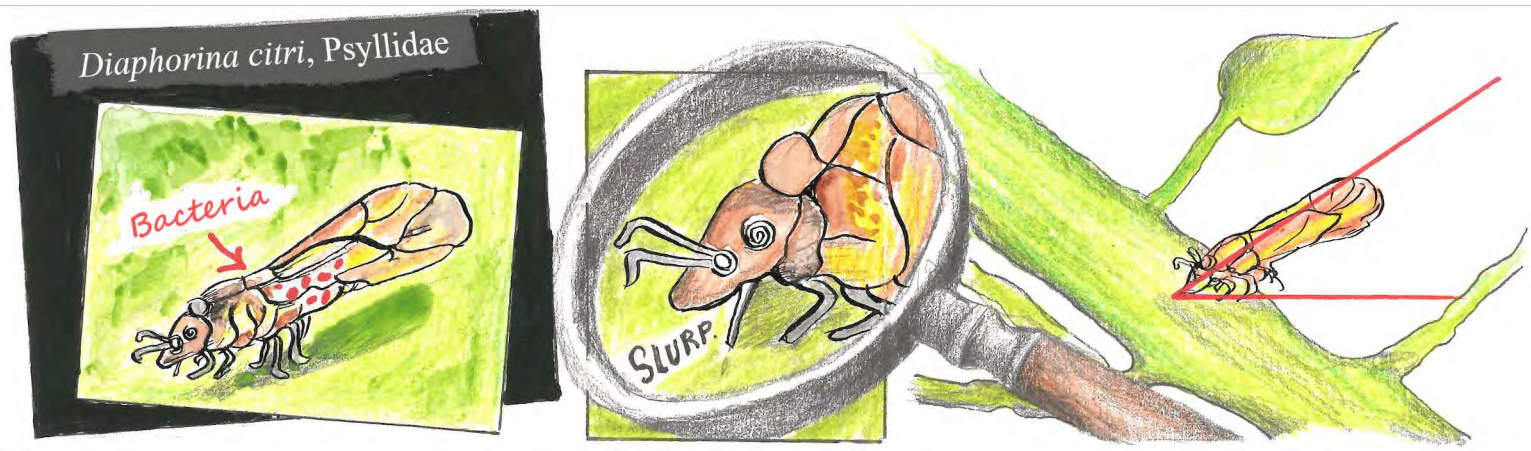
... the psyllid responsible for the disease!

Hello!

Oh!

Liviidea, *Diaphorina citri*

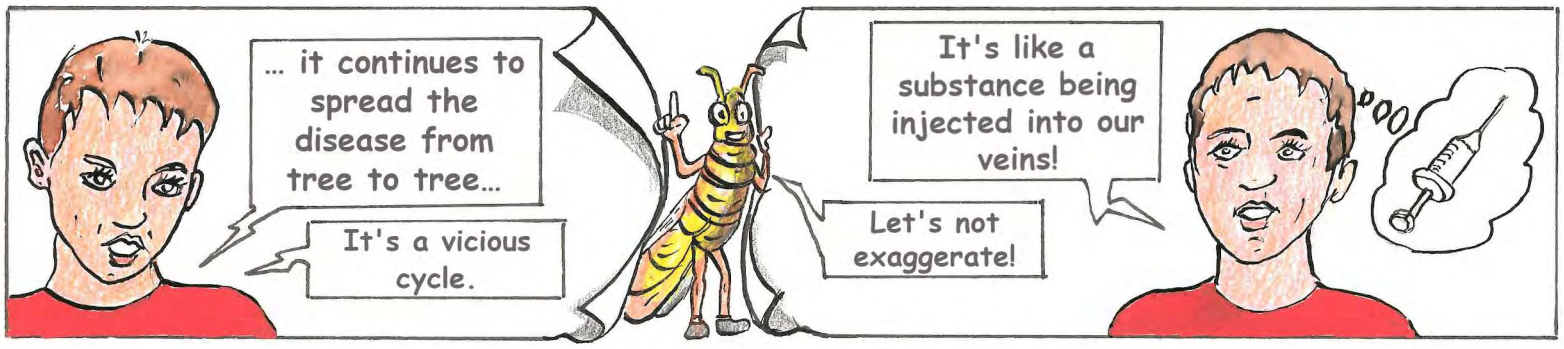
PR PLONK

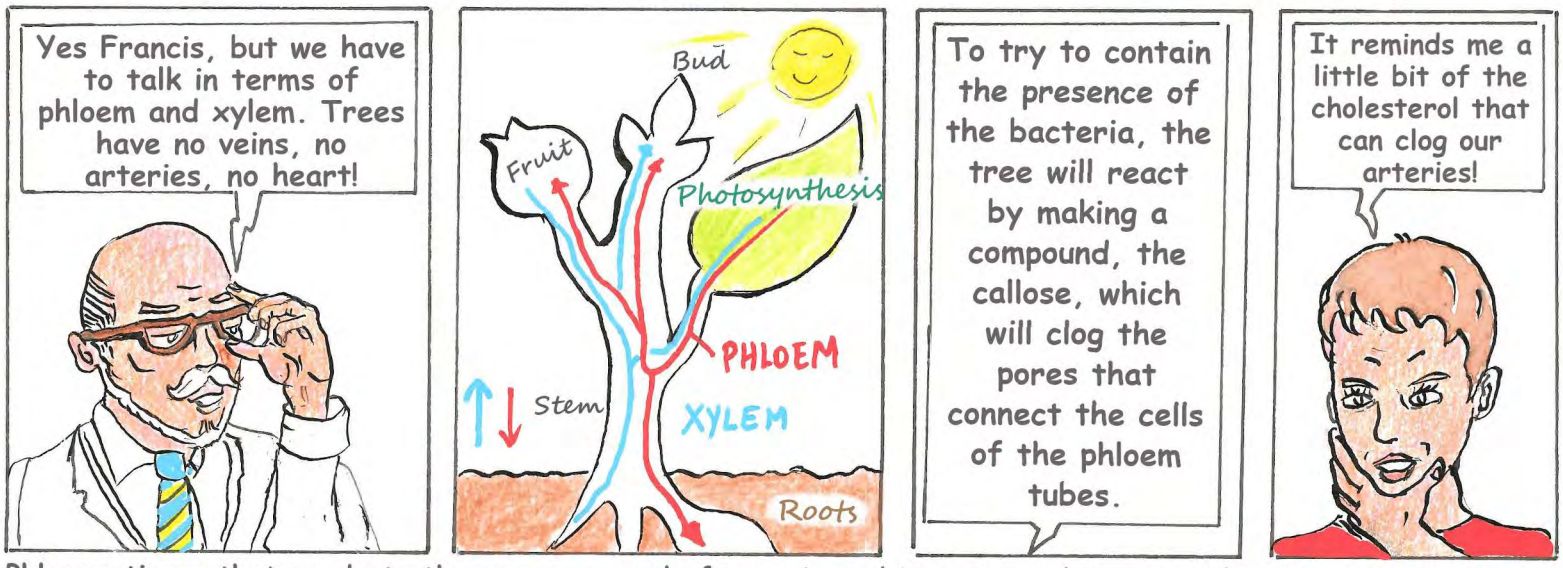


It feeds on the vascular system of the plant. It belongs to the order of insects that also includes aphids. It is brown with mottled wings.

It has a stylus that allows it to feed by extracting the sap from the tree.

The insect maintains a distinctive 45-degree tilted position. It is often identified by this characteristic posture.





Phloem: tissue that conducts the sap composed of organic and inorganic substances, that is synthesized in the leaves and distributed throughout the plant.
Xylem: tissue that conducts water and micro- and macronutrients from the roots to the aerial parts.

Hmmmm, yes Francis! The comparison is interesting! Following the clogging of the phloem vessels, the sap will no longer be able to move.

This engorgement of sugars in the leaves disrupts the photosynthesis and the leaves turn yellow!

Photo-synthesis

Anyway, this overreaction of the tree is actually a disaster. Also, trees get worse...

... if they undergo other stress such as drought.

Are you checking out, Francis?

No, professor! I'm just wondering if there's no way to heal the trees?

Today, there is no treatment that can cure a tree once it has been infected.

And the insect? Is it the only vector of this disease?

Your question is pertinent, Francis! Unfortunately, humans unknowingly help spread the disease...

... by transporting infected grafts from one region to another. So, I must tell you about the grafting technique, Francis!

The grafting technique consists in making a fragment of a plant of interest fuse to another plant, called rootstock, which will receive the graft.

Chip of the plant of interest

Graft

Rootstock

Graft

This technique allows one to multiply a variety of interest and to benefit from interesting characteristics, in terms of resistance or physiology, provided by the rootstock. It is during this operation that the disease can be transmitted...

Bacteria

Graft

Bud

PHLOEM

XYLEM

PHLOEM

XYLEM

PHLOEM

XYLEM

Unfortunately there are yet other ways of transmission of the disease.

As if these difficulties weren't enough!

Yes! There is the orange jasmine (*Murraya paniculata*). You know, that ornamental plant that make nice-smelling .

There's a lot of it, and psyllids love it...

This shrub is related to citrus and does not develop the disease symptoms. And as long as we maintain this vector...

...we maintain the disease! This is a serious situation.

So, we have to remove the orange jasmine and all the diseased trees... How unfortunate!

Only in theory... because on small territories with very small orchards, this is almost impossible.

Today, a great care is taken to replant only certified healthy trees, which limits the spread of the disease.

But can't we control this insect? I imagine that it moves from branch to branch, even for miles...

But to imagine that it can cross the oceans, I don't follow you anymore, Professor!

Hold on, young man! Here we go! Air currents probably carry the psyllids...

Pr Bellerose, historian

... but also, and above all, international trade...

... and population movements from one country to another, as history often attests.

Remember, Francis, the grafting technique!

Yes, but what do you mean? When we travel, we don't take plants with us!?

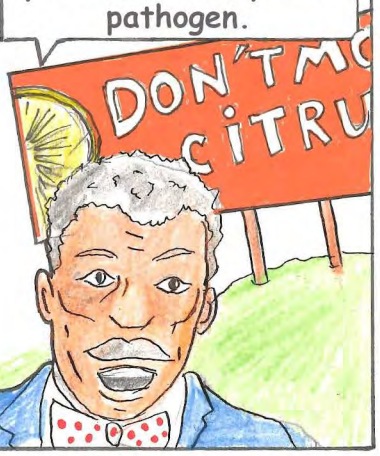
Alas, Francis, we do! When you definitively leave your country, you bring your culture and traditions with you, and sometimes also plant material such as grafts or seeds.

This is how a disease can spread to a new land.

Gosh! What a complication, indeed! But then...

... travelers must be prohibited from exporting citrus fruits!

That's correct, lad! This will prevent the contagion of areas not yet affected by this pathogen.



... And uproot all the diseased trees, right?

Yes, Brazilians are uprooting infected trees and replanting healthy ones over hundreds of acres.

It's sad, what a waste!

But I no longer understand... If all the plants in a country are sick or uprooted... where do healthy trees come from?

In many countries, such as France, there are collections of healthy trees. In Corsica* plants are kept healthy, preserved from disease, and sent to Guadeloupe, Martinique or Reunion...

... to be grafted on rootstocks and propagated in greenhouses. But once planted outdoors, the trees end up being contaminated again...

Sa ké bon memm!**

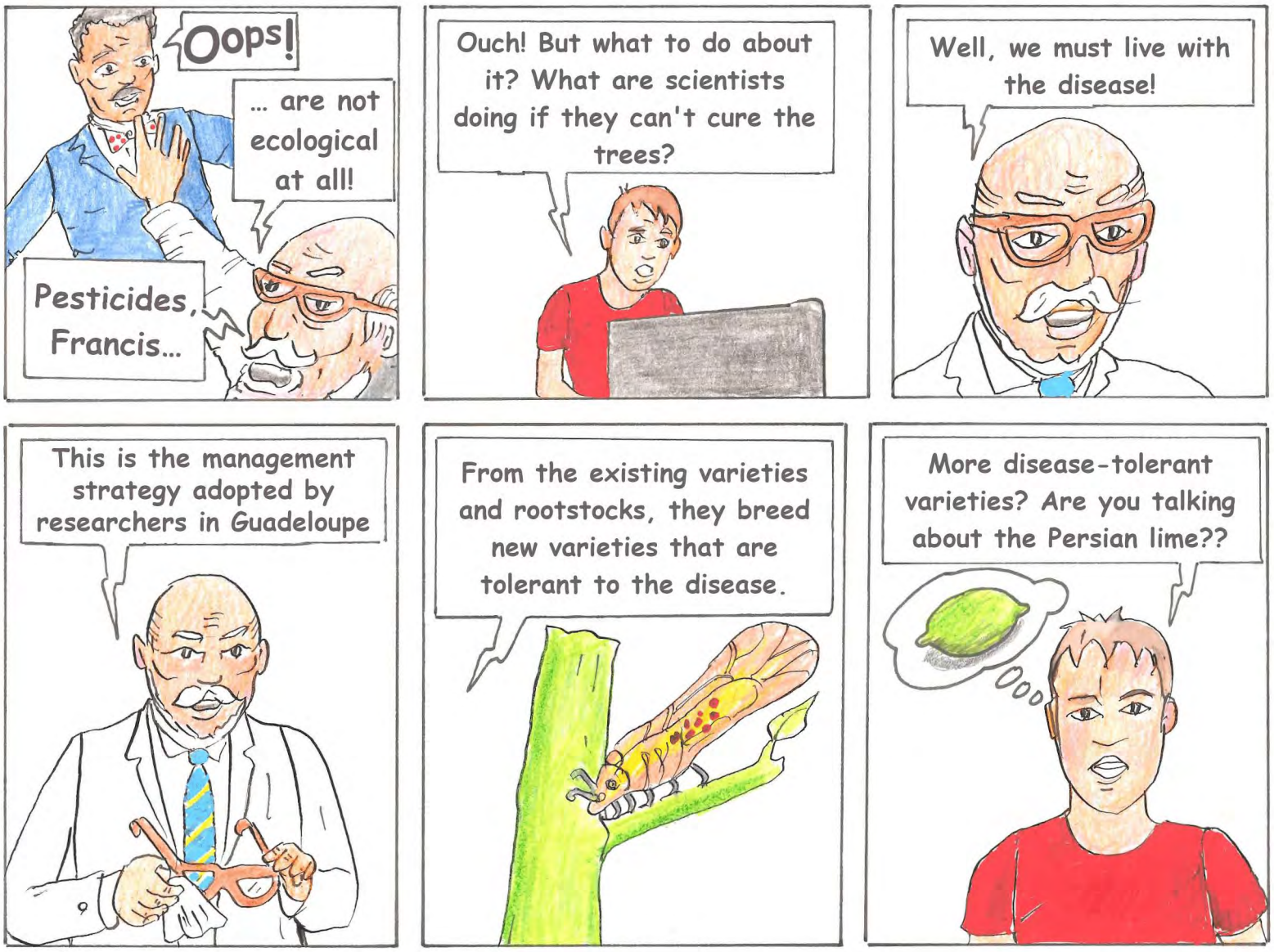
Oh, what a pain in the neck! Then what about pesticides?

Yes, pesticides are used against psyllids in many countries...

... especially in Brazil to prevent reinfection of large replanted areas.

*BRC Citrus: Biological Resources Center where the diversity of citrus species is conserved.

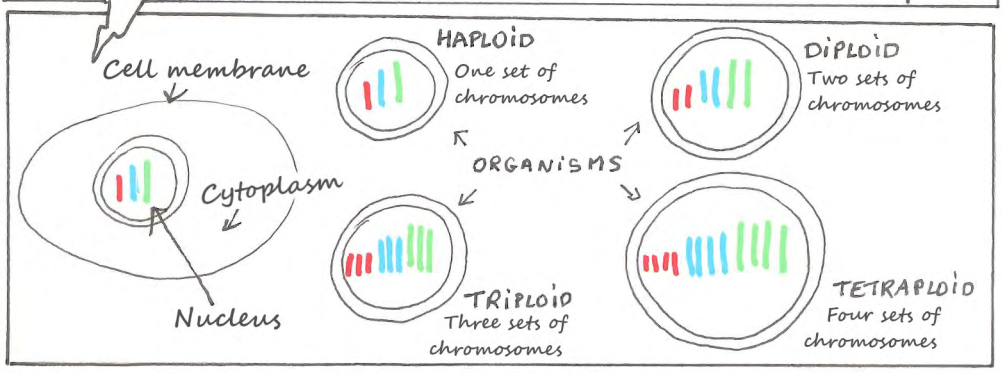
**"Ooh, yummy!".



DNA is a linear molecule that carries the genetic information in all known living organisms. It is stored in the nucleus of the cell in the form of chromosomes.

Here we are touching on the notion of polyploidy, dear Francis. Ploidy is the number of chromosome sets that a species has. Most species have two pairs of each chromosome, that is, they are diploid. Polyploid species are those that have a ploidy number greater than two...

In plants, it is not uncommon for the number of chromosome sets to be greater than two. In the case of the Tahitian lime, there are three sets; we then refer to them as triploid. Some plants even have four sets of chromosomes; in this case we call them tetraploids.



In citrus, there are nine chromosomes. This schema shows only three chromosomes for the sake of clarity.

Studying the behavior of polyploid plants in relation to the disease, scientists have observed that they display several interesting traits.

First, triploid trees are better adapted to the disease...

... than diploid trees.

Are you still following me, Francis?

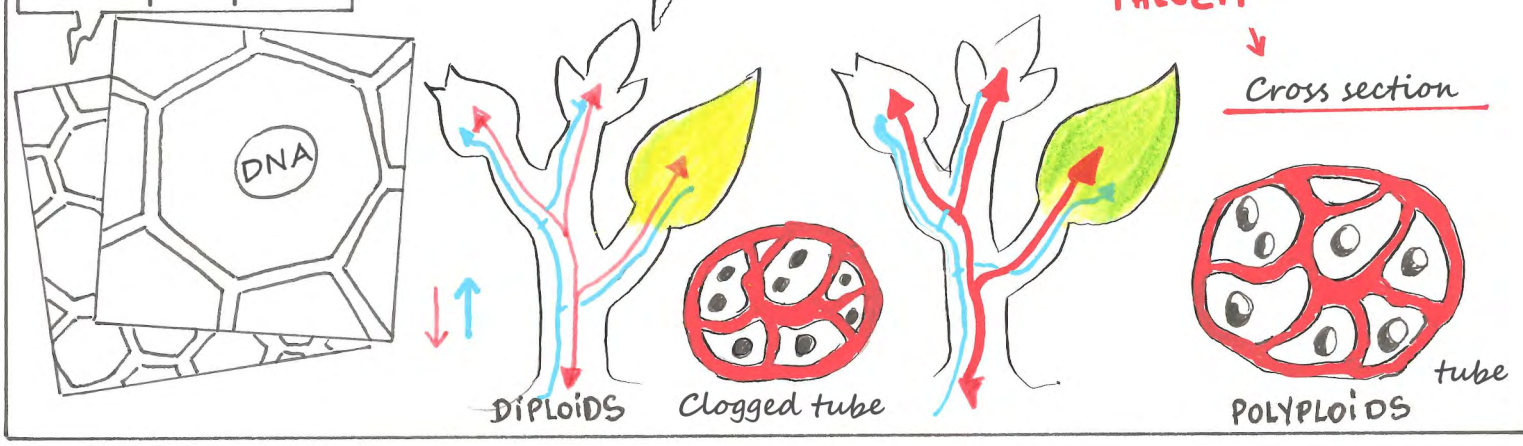
All right, all this is exciting!...

... and it gives you a little hope. But what other benefits do these polyploid trees bring?

Well, polyploid trees can better tolerate stressful environments.

Polyploid plants produce larger cells than diploid plants.

Thus, in polyploid citrus, the diameter of the vessels increases, and the vessels are less clogged.



I wonder if scientists are also looking at ways to optimize the natural resistance of trees?

Indeed, investigations are also focused on adapting irrigation methods and providing optimal fertilization...

These factors, among other things, greatly reduce the impact of the disease on the trees and ensure continuous fruit production.

So we need to encourage farmers to upgrade their practices and encourage them to use irrigation and groves fertilization!

You've understood everything, Francis! But many questions remain about the HLB.

The work continues assiduously in many parts of the world, as scientists continue to work very hard to solve the HLB problem, working on the vector, the bacterium and the citrus plant.

Scientists hypothesized that the plant's root system constitutes a "black box" that determines the impact that the disease will later have on the rest of the plant...

?

Thus, the results of several European Union-funded projects on rootstocks should also provide information on the mechanisms at work in the root system...

... and perhaps, then, breed resistant varieties able to stop the spread of the disease throughout the plant...

Thank you very much, Professors, for these interesting explanations about the yellow dragon disease!

CLAC

Goodbye, Francis! And see you soon!

Francis, there was only one bottle left at the supermarket!

Shortage already? Are you kidding, Mom?

Obviouslyyy, I'm joking!

Come on! This is a very serious issue!

THE END

But, Pr Plonk, all these investigations must be very expensive?

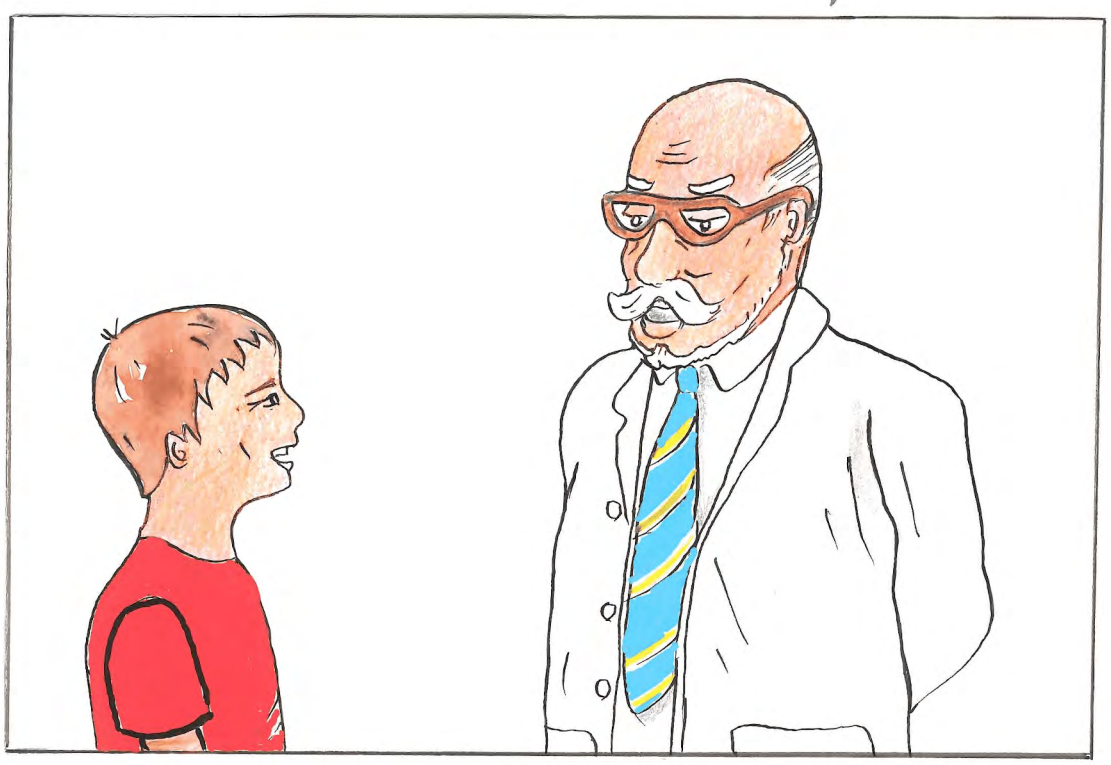
You're right, Francis!
All this research requires important investments.

Fortunately, research can progress thanks to funding from the European Union.

In the French West-Indies, I can mention the ERDF project CAVALBIO and the EARDF project PARADE HLB, the latter funded in the frame of the Agricultural Innovation and Transfer Network in french oversea territories (RITA).

At the international level, there are the Horizon H2020 projects TROPICSAFE and Pre-HLB, and the LIFE project VIDA FOR CITRUS.

Finally, private companies including Grand Marnier and Cointreau, in France, and Les Domaines Agricoles, in Morocco, are also important contributors to the effort.



Since 2015, the “Structure of Citrus Evolution, polyploidy and genetic improvement” (SEAPAG) team, from the AGAP unit at CIRAD, has been developing investigations to produce citrus fruits in spite of the presence of HLB. In this photograph, the technicians, PhD students, engineers and scientists of the team in Guadeloupe, pose in a plot of innovative triploid lime trees.

cirad
AGRICULTURAL RESEARCH
FOR DEVELOPMENT

The author

Cécile MORILLON is a professor of Plastic Arts and holds a PhD in Art History on the thermal architecture of Vichy (1853-1914) and other water cities, obtained at the University of Clermont-Ferrand. Drawing and painting since her childhood, she devotes her spare time to comic books, which she considers a language capable of conveying contents both varied and complex. The question of the "yellow dragon" was an opportunity to approach a current scientific subject through this medium in an entertaining way.
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The contributors

Hervé RABILLE holds a PhD in plant cell biology from the Roscoff Marine Biology Station. Fan of books and scientific culture, he has left the laboratory bench to pursue a career in science journalism and communication. At CIRAD in Guadeloupe, he is now Communication Officer for the ERDF Cavalbio project. He participated with enthusiasm in the elaboration of this comic book by gathering and synthesizing valuable scientific information for the project.

Raphaël MORILLON & Patrick OLLITRAULT are senior scientists at CIRAD. They are both in charge of citrus research programs to propose solutions to deal with HLB disease. Together with Hervé RABILLE, they have been members of the scientific committee.

Hervé RABILLE and Dr. **Christopher VINCENT** (University of Florida, Department of Horticultural Science), translated the comics into English.

H2020 project
"Preventing HLB epidemics for ensuring citrus survival in Europe"