Phytophthora ramorum

Plant pathologists track where it came from and how it has managed to spread

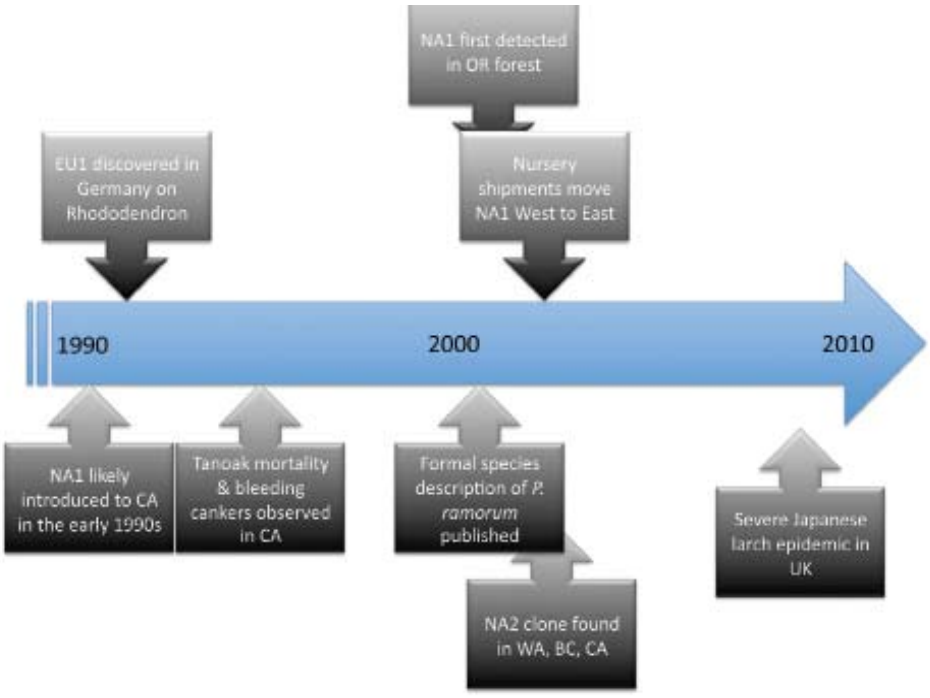

Figure 1: Chronology of the emergence of *Phytopthora ramorum* in North America

By Niklaus Grünwald

Phytophthora ramorum likely arrived on the U.S. West Coast five to 15 years before being noticed in the mid-1990s.

At the time, the pathogen was not even known to science. Plant pathologists had a hard time recognizing the disease symptoms as being caused by a new *Phytophthora* species, *P. ramorum*.

Nursery growers had long known the *Phytophthora* genus was causing problems on woody ornamentals. But little did we know what impact this pathogen would have on our native forests and the nursery industry.

The pathogen has caused disease epidemics on tanoak, California live coast oak and more recently, Japanese larch. Figure 1 provides a chronology of the emergence of *Phytopthora ramorum* in North America since its

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Clone	Distribution	Habitat	Mating type
NA1	North America	Forests, Nurseries	A2
NA2	North America	Nurseries	A2
EU1	Europe, North America	Forests, Landscape, Nurseries	A1

Table 1: Characteristics of the three clones of *Phytophthora ramorum*.

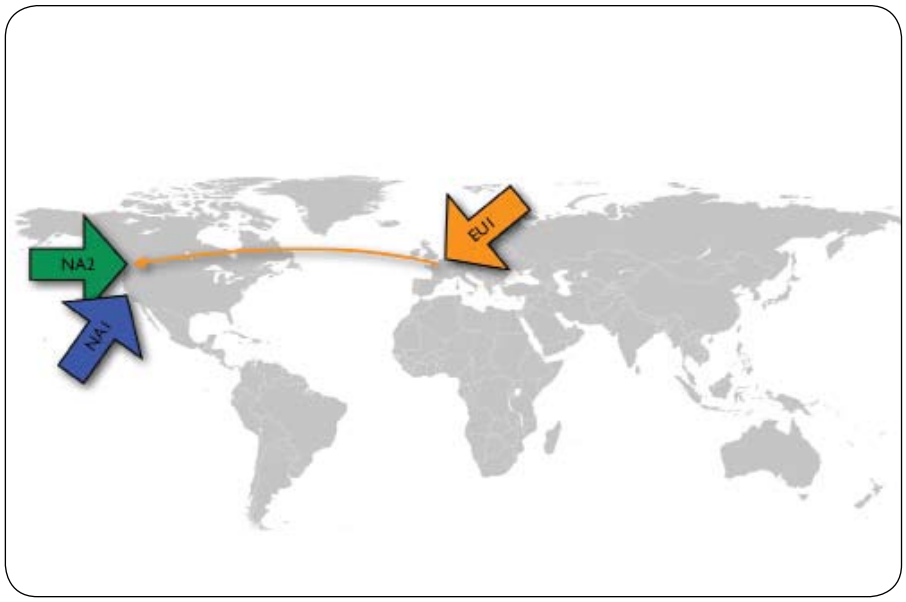

Figure 2: Movement of NA1 pathogen from Europe

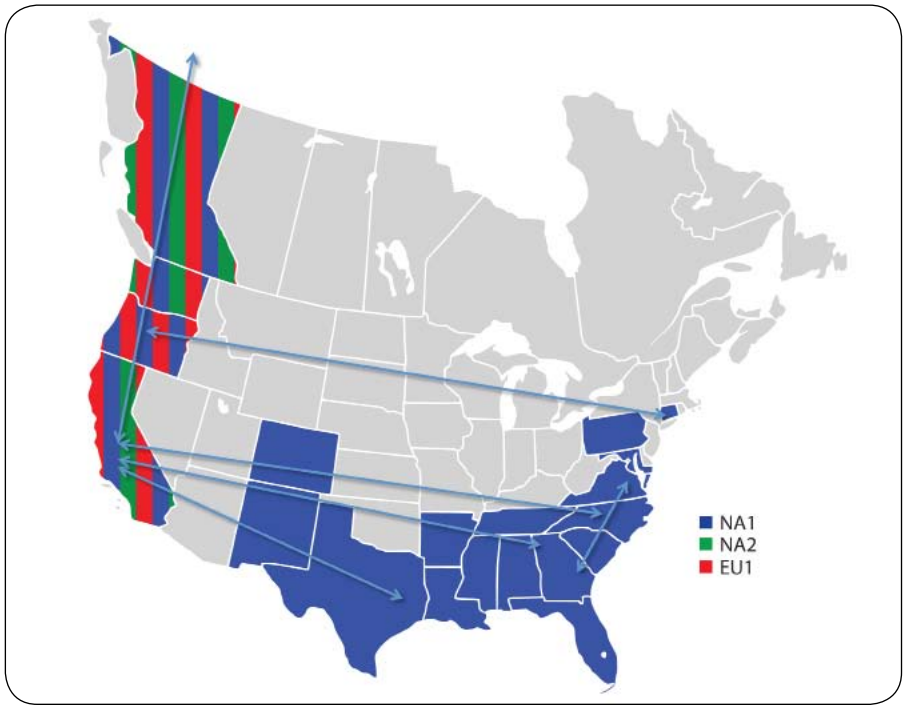

Figure 3: Detection of *P. ramorum* clones

first discovery in California, detailing the appearance of different clones and major migration events.

Clones and mating types

Although *P. ramorum* has been detected only in North America and in Europe, it is not native to either of those continents. Its lack of sexual reproduction and its clonal nature indicate that the pathogen is foreign.

There are now three known variants or clones of the pathogen that propagate asexually and do not cross-breed. These clones are referred to as NA1, NA2 and EU1. The names of these clones are derived from the continents on which they were first found.

Some *Phytophthora* species have two mating types, which are referred to as A1 and A2. Others can self-fertilize and do not require the opposite mating type.

In *Phytophthora* species that have two mating types, A1 and A2 isolates are needed to produce sexual spores known as oospores. *P. ramorum* clones NA1 and NA2 are of the A2 mating type, while EU1 is of the A1 mating type (Table 1).

Although *P. ramorum* has both mating types, sexual reproduction has not been detected in areas where both mating types coexist. A recent study showed that the three clonal lineages — NA1, NA2, and EU1 — have not mated in several centuries. This long divergence of clones might explain the apparent lack of sex in *P. ramorum* .

The absence of sex is good news, as sex can provide a pathogen with the opportunity of evolving faster to produce more aggressive strains better adapted to our cropping practices.

Tracking the pathogen

How do we track the migration of this pathogen? Scientists have used genetic markers that reveal subtle variations in DNA sequence to study genetic diversity and migration of *P. ramorum* both within the continental U.S. and globally.

These genetic markers are the same tools used in human forensic science

These genetic markers are the same tools used in human forensic science to determine parentage or to identify a suspect based on a DNA match. These powerful genetic tools show increasing diversity within a clone over time (Figure 4). The genetic diversity provides information allowing scientists to unravel the pattern of movement among populations, continents, and/or individual nurseries.

At least four intercontinental migrations have occurred.

The first documented clone, NA1, is the one responsible for outbreaks in California and Southern Oregon (Figure 2). Detailed population studies have shown that the NA1 pathogen was most likely introduced into California, potentially via imports of exotic ornamentals. Further studies have demonstrated that the NA1 clone has spread up and down the West Coast, and from the West Coast to the Southeast and East Coast.

Most recently, NA1 has also been moved with shipments of ornamentals across state boundaries on the East Coast (Figure 4). The NA1 lineage is the most widely spread lineage as it was shipped across the continental US in extensive nursery shipments in 2004 and more recently (Figure 3).

Recent studies showed that the NA2 lineage was introduced into the Pacific Northwest — either British Columbia

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▲ PHYTOPHTHORA RAMORUM

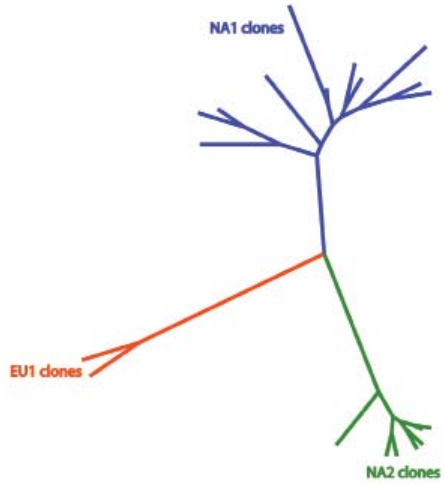

Figure 4:

or Washington — and is also found in California (Figure 3). The NA2 lineage is found less commonly in nurseries and has not been found in forest vegetation. It has not been found in Oregon (Figure 3).

The EU1 lineage is more widespread in the U.S. than the NA2 clonal lineage and also exists predominantly in the nursery environment (Figure 4). It too was introduced into the Pacific Northwest and came via Europe to North America. Recently, the EU1 clone was found infecting large commercial Japanese larch plantations in England and Ireland, forcing an early harvest of these trees in an attempt to slow the spread of the pathogen.

Scientists are still looking for the origin of the NA1, NA2, and EU1 clones. We only know that they are not native to Europe or North America.

The differences between NA1, NA2 and EU1 are largely genetic. There are also subtle differences in appearance and pathogenicity. The NA2 and EU1 clones are generally more pathogenic to plants, although all clones readily cause disease on susceptible ornamentals and tree hosts. None of the clones show any preference for a host.

How is *P. ramorum* moved long distance? The four documented intro-

ductions of the pathogen (Figure 2) are most likely the result of repeated shipments of infected nursery plants including rhododendron, camellia or potentially others. USDA APHIS records show that rhododendron plants have been repeatedly imported into North America from other continents.

Furthermore, it is clear that highly susceptible nursery plant material continues to be imported, although the number of shipments have declined in recent years.

It's worth noting that the large *Viburnum* shipments in 2007 (302,858) and 2008 (96,354) came from a single source. Thus, *P. ramorum* can still potentially be moved across international boundaries.

Conclusions

This exotic pathogen has repeatedly moved among continents.

We also have yet to identify the native geographic range of the pathogen; thus, we are at risk of additional introductions. Other diseases posing similar threats, such as *P. kernoviae,* still lurk in various corners of the world.

As these pathogens can be moved by nursery stock, it is important that growers adopt practices that lower the risk of inadvertently introducing and moving these quarantine pests with their products.

Hobbyists and plant collectors should also be aware that moving plants without proper care or caution can result in inadvertent introductions of new non-native pathogens.

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