COMPOSTING AS A CONTROL FOR SUDDEN OAK DEATH DISEASE

Laboratory and field research is showing that a disease affecting a large number of native trees, shrubs, and herbaceous plants in California and Oregon may be eradicated during temperature-controlled composting.

Matteo Garbelotto

SUDDEN Oak Death (SOD) is a tree disease affecting a large number of native trees, shrubs, and herbaceous plants in the central coast area of California and southern Oregon. First noticed in 1993, its symptoms did not match any known forest disease. In 2000, scientists were able to isolate the primary causal agent. It was a species of Oomycete, fungus-like organisms more closely related to brown algae and kelp, than to the proper fungi. The organism belongs to the well-known genus *Phytophthora*, which includes many aggressive plant pathogens responsible for historical epidemics like the Irish potato famine of the nineteenth century, the Jarrah die-back in Australia, and oak decline in southern Europe.

The species isolated in California, however, did not match any known species. In 2001, it was named *Phytophthora ramorum* — an odd Greek-Latin binomial that literally means "destroyer of plant branches." Why was this name adopted for a pathogen known to cause girdling cankers in the main stems of majestic oaks and tanoaks? The reason for the name lies in the fact that the same microbe had been isolated in 1993, several years prior to the California discovery, from branches and leaves of rhododendrons in plant nurseries in Germany and the Netherlands.

Once the European-U.S. connection was made, it was discovered that the pathogen also could be found in California woodlands on leaves and branches of plants other than oaks and tanoaks. The list of hosts grew, including species such as Pacific madrone and huckleberry, which may be killed by the pathogen by girdling of the branches one by one, rather than girdling of the main stem as occurs in oaks. In other instances, the disease appeared to merely cause spots, blotches or scorching of the leaves without leading to any significant further deterioration of the health of the affected plants. This was, and still is, the case for plants like California buckeye, California bay laurel, and big leaf maple. It was subsequently understood that these hosts, dubbed as "foliar" to distinguish them from the "stem" hosts such as oaks and tanoaks, played a major role in the epidemiology of the disease.

Bleeding of a viscous sap through the intact bark is a symptom of infection by Phytophthora, including *P. ramorum* (upper photo). View of a tanoak-redwood forest in Big Sur, California (lower photo, right), shows where tanoak mortality has reached 90 percent.

It is on the leaves of some of the foliar hosts, and in particular of bay laurel, that the pathogen can rapidly become established. In just a few days, copious amounts of infectious propagules can be splashed from the leaves' surfaces onto the bark of oak trees, infecting them. Death occurs when the pathogen kills the cambium around the entire stem circumference. Despite its aggressiveness on oaks and tanoaks, the microbe is only mildly pathogenic on the foliar hosts — ensuring its long-term survival in most woodlands it reaches. As in all plant diseases, climate plays a major role in disease progression. The moist and cool weather of coastal central California is optimal for the infection and growth of the pathogen.

WHY WORRY ABOUT SOD?

SOD has become a major issue at national and international levels, not only because of the significant devastation it has caused among California oaks and tanoaks, but also because of the high levels of uncertainty associated with it. The uncertainty is caused

The issue at stake here is whether this deadly tree pathogen could be spread through commercial compost. A second issue is whether composting may be utilized as a way to sanitize infected green waste.

by only partial understanding of its biology, and results in our inability to make accurate predictions on its spread and impact. Significant effort has thus been placed to ensure that the artificial spread of the disease is not enhanced by human activities. Known plant hosts are regulated, and in some cases, host plants, or some of their parts, cannot leave the area in which the infestation of *P. ramorum* is known to occur, unless certified to be uninfected.

Because symptoms are not always extremely obvious, especially in the case of foliar hosts, and because plants can still be harboring the pathogen without displaying any symptoms, it is often extremely difficult to determine whether *P. ramorum* may be present. This difficulty is compounded by the fact that infectious resting propagules can survive in the soil, as is the case with many other *Phytophthora* species.

Is there a risk associated with the movement of *P. ramorum*? Judging by levels of local mortality, approaching 50 percent for coast live oak and 90 percent for tanoaks in the worst hit sites, the concern is fully justified. Greenhouse experiments also have shown many non-California species to be highly susceptible, including Northern Red Oak, the most widespread oak species in the East Coast and Midwest. Finally, we are learning that not all individuals belonging to this pathogenic species are equally aggressive. The introduction of *P. ramorum* is particularly worrisome because this pathogen is known to be not only soilborne and waterborne like most other forest *Phytophthoras*, but it also is the first temperate forest *Phytophthora* known to be able to spread aerially.

These infected California bay laurel leaves are extremely infectious, and responsible for natural spread of the disease in California.

COMPOST AND SOD

Although *P. ramorum*, like most other *Phytophthora* species, requires a live host to become established, it is also capable of surviving as a saprophyte (i.e. feeding on decaying organic matter) in the plant tissue after the plant is dead. Isolates of *P. ramorum* have been successfully obtained from tanoak bark several weeks after trees had been downed. Similarly, bay and rhododendron leaves can be dried but upon rehydration after several weeks they are still infectious. Although live plants and moist infested soil rank as the most likely avenues for artificial spread, green waste and to a lesser extent, wood, also may be involved in the artificial spread of the disease. When infected fire logs, wood chips and branches are kept in a cool and moist environment, they can harbor viable *P. ramorum* for long periods of time. Because these substrates are commonly brought into commercial composting facilities, it is of great importance to determine whether at the end of the composting process, *P. ramorum* may still be viable.

The issue at stake here is whether this deadly tree pathogen could be spread through commercial compost. A second issue, of regional rather than national relevance, is whether composting may be utilized as a way to sanitize infected green waste. It is in fact estimated that about 10 million tons of green waste infected by *P. ramorum* are accumulating in coastal California per year. Because of the risk of contagion, it is often recommended that the materials remain at the site of infection, leaving landowners with limited options. The reason for this caution is that SOD is a disease with patchy distribution. Even in the worst hit areas, many woodlands are still unaffected. Because of the presence of many local composting centers, composting may represent a viable and useful approach to dispose of infected plant material, without the need for long hauls.

Monica Meija-Chang places plant material infected by *P. ramorum* in an incubator set at 131°F.

There is a rich literature documenting the ability of composting to sanitize a variety of substrates from animal and plant pathogens, including viruses as well as weed seed. But what about *P. ramorum*?

LABORATORY TESTS ON *P. RAMORUM*

Although much could be said about the microbial activity during the composting process and its antibiotic effects, the unifying criterion of an appropriate composting process is defined by exposure of the raw substrate to high temperatures for an extended period of time. These high temperatures are generated by cumulative respiration of the microbial flora in the compost pile, and are achieved in different ways by changing the size and composition of the pile, the frequency of turns, forced aeration and the amount of water in the pile. No matter how high temperatures are achieved, California composting regulations stipulate that in commercial composting, a minimum temperature of 131°F has to be maintained continually for a certain time period. For instance, in windrow piles, by far the most common composting approach in California, this temperature has to be maintained for 14 days.

P. ramorum is known to be a cool climate species with optimal growth between 64° and 71° F. In August 2001, we set out to determine its tolerance for high temperatures in our laboratory at the University of California, Berkeley (UCBerkeley). These studies were particularly relevant because *Phytophthora* species produce both asexual (chlamydospores) and sexual (oospores) resting structures that allow them to survive during unfavorable climate or when susceptible hosts are not present. *P. ramorum* is known to produce large and abundant chlamydospores.

In a first round of experiments, Petri dishes with growing colonies of three different *P. ramorum* isolates were placed in heat incubators set at 72°, 95°, 104°, 113°, and 131°F for varying periods of time. Results indicated that a 30 minute exposure even at the highest temperature was not enough to arrest the growth of the pathogen. On the other hand, one hour at 131°F, two hours at 113°F and 24 hours at 104°F were sufficient to completely arrest the growth of the colony. Chlamydospores were not capable of germinating after exposure to 131°F for one hour, suggesting that the temperature parameters of the composting process may suffice to sanitize plant material infected by *P. ramorum*.

In a second series of three experiments, we placed plant material infected by *P. ramorum* in a heat incubator set at 131°F. Tested material included coast live oak wood chips, bay laurel leaves, and infected coast live oak stems with diameters ranging between two and three inches. Plant material was sampled after one and two weeks. An unexpected result of these tests was the discovery that one week of heat treatment effectively sanitized the woody substrates (chips and stems), but not the bay leaves. This result is explained by the fact that the formation of chlamydospores is rare on wood, but frequent on leaves. Because chlamydospores are embedded in a solid matrix (e.g. the leaf parenchyma) rather than in a gelled growth media (e.g in the Petri dishes), they are more resistant to high temperatures than observed when placing pure cultures in the incubators. Nevertheless, after two weeks, all plant material was always free of *P. ramorum*.

COMPOSTING FIELD TESTS

In order to confirm *P. ramorum* would not survive the composting process, a series of field studies was designed and performed between December 2001 and December 2002. The studies consisted of placement of infected and infectious plant material in compost

Results from these experiments also indicated that *P. ramorum* in small size woody substrates, such as wood chips, will lose viability if air dried, even without going through the composting process.

TREATING DISEASED GREEN WASTE AT COMPOSTING SITES

Pat Paswater

RECENTLY, the California Integrated Waste Management Board (CIWMB) partnered with Matteo Garbelotto at the University of California, Berkeley (UC Berkeley) and commercial composters to research the composting of Sudden Oak Death (SOD) host material. Recognizing the importance of protecting markets for recycled content products established by local jurisdictions and lessening the impact of SOD regulation on composting operations within the 12-county area subject to SOD regulations, the CIWMB has allocated $50,000 towards this effort. Research data generated during the last 18 months is being compiled to show that the composting process kills the newly identified pathogen, *Phytophthora ramorum.*

One regulatory concern focuses on the risk of spreading the pathogen in green material from the 12-county regulated area to other California counties. Since it is difficult to determine the plant species of commingled trimmings, green material is subject to regulatory scrutiny even if there is no host material present. Currently, no regulated or restricted material within the quarantine area can be moved without a permit issued by CDFA. Technically, this means green material originating within an infested county cannot be composted, landfilled or burned for energy either outside or within the quarantine area unless permits are obtained. Few permits have been issued to date, but municipal green material continues to be collected, moved and processed with the knowledge of the observant regulatory authorities operating in the quarantined twelve-county area.

The state quarantine for *P. ramorum* has created concern within the collection and transportation infrastructure of curbside-collected organic materials throughout northern California. In 2003, when the state and the federal quarantines for *P. ramorum* will harmonize, CIWMB staff anticipates that many organics recycling businesses may be negatively impacted in the following counties: Alameda, Contra Costa, Humboldt, Marin, Mendocino, Monterey, Napa, San Mateo, Santa Clara, Santa Cruz, Solano, and Sonoma.

As discussed in the accompanying article, the UC Berkeley field research results from aerated static pile and windrow composting trials indicates that SOD contamination in green material presents little or no risk for spreading the pathogen if the product is composted and protected from exposure to additional *P. ramorum* inoculum. Research documentation will be submitted to state and federal regulatory staff for consideration of composting as an alternative treatment for SOD in early 2003. If composting is approved as an alternative treatment, CIWMB-permitted composting operations could provide another option for removal of high hazard diseased trees. These operations also could reduce the amount of SOD inoculum present in the regulated area.

At the very least, regulatory approval of SOD host material treatment by the time-temperature process of composting would provide some relief to local jurisdictions in the 12-county regulated area. This would also apply to the CIWMB-permitted operations producing compost and composted-mulch products. For a current list of the quarantined counties, the variety of SOD hosts, and the numerous articles regulated, please visit the California Department of Food and Agriculture's Web site at http://pi.cdfa.ca.gov/pqm/manual/455.htm.

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Steven Swain and Jeff Creque place mesh bags containing infected plant material in the compost pile.

piles at the beginning of the process, and in the analysis of *P. ramorum* viability 14 days later. The composting materials were sampled four times, (i.e. in four different locations in the pile), in two windrows and in one forced air facility. Each experiment was repeated twice. Infected plant material consisted of ten coast live oak wood chips, ten bay laurel leaves, and one cankered coast live oak stem placed in a mesh nylon bag, to ensure contact with the compost pile. As stated above, four bags/pile were employed. Temperature recorders also were included to monitor temperature fluctuations, and at each turn of the pile, mesh bags were removed and then placed back in the pile. Four mesh bags were also kept as controls in a moist and cool environment at UC Berkeley.

Results of each trial unequivocally showed that while the plant material stored at UC Berkeley remained infectious, all material coming out of the compost piles was not infectious. Plant material was tested both by plating small portions of plant tissue on a *Phytophthora*-selective medium, and by flooding entire leaves or piles of wood chips, and baiting *P. ramorum* with pears. When water is present, and if the pathogen is still viable, biflagellate zoospores will be produced. These organisms swim short distances and infect susceptible substrates, including pears. In our trials, none of the pears were found to be infected by the zoospores.

Results from these experiments also indicated that *P. ramorum* in small size woody substrates, such as wood chips, will lose viability if air dried, even without going through the composting process.

CONCLUSIONS

Our controlled laboratory and field experiments have indicated that the temperature and time parameters federally stipulated for commercial composting are sufficient to sanitize plant material infected by *P. ramorum*. It should be noted that all of the experiments conducted at UC Berkeley to date have involved relatively small amounts of infected plant material. A series of tests using large amounts of infected material are currently underway. These larger scale experiments have been designed to provide managers of composting facilities with data regarding the infectivity of runoff water, the ability of propagules to be windblown off the compost pile into the surroundings, and the possibility that sanitation may not be equally effective everywhere in the compost pile. This information will be valuable in the design of guidelines to minimize the possibility of spread of the disease during the composting process, before all of the microbial propagules have been killed.

Although we have shown composting is an effective sanitation tool, the composting operation needs to be run with care and following standards established by the California Integrated Waste Management Board (CIWMB). In our experiments, for instance, we have recorded fluctuations of temperature. Pronounced temperature shifts may adversely affect the inactivation of the pathogen. In more recent and preliminary experiments, we also have shown that resting *P. ramorum* propagules may survive if placed in mature compost. This possibility underlines the need to clearly separate mature from raw compost in commercial facilities. It is an ethical responsibility of the manager of each facility to ensure Sudden Oak Death is not spread through inappropriately produced or handled compost. ■

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