Research Update on Propiconazole as An Effective Tool for Managing Oak Wilt

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Without a doubt, oak wilt is the most devastating disease of oaks in the Midwest. Red oaks (including northern red oaks and northern pin oaks) are particularly susceptible, and once infected, these trees can be killed in just a few weeks. Oak wilt is caused by a fungus (Ceratocystis fagacearum) that invades the water-conducting portion of a tree's vascular system, causing rapid wilting and death. When a tree is killed, the fungus spreads downward into the root system and across root grafts to neighboring trees. In stands where susceptible oaks are prevalent, the fungus will continue to spread from root system to root system killing trees, resulting in an oak wilt disease center.

Managing oak wilt in disease centers is notoriously difficult. Once a red oak begins to wilt, there is nothing that can be done to save it, so disease management focuses on preventing new trees from becoming infected. Traditionally, root graft disruption (severing grafted root systems with trenching equipment or a vibratory plow) has been used to restrict the pathogen from spreading through a stand. Injection treatments of the systemic fungicide propiconazole are increasingly being used to protect high-value oaks that are near diseased trees, particularly those inside trench lines or on sites where root graft disruption cannot be conducted. When used properly, propiconazole can provide effective protection from oak wilt for approximately two years.

While numerous studies have demonstrated the effectiveness of propiconazole, there have been a number of lingering questions about these treatments that have gone unanswered for many years. As part of my PhD research at the University of Minnesota, I and cooperators from the USDA Forest Service Northern Research Station set out to answer some of these questions, but to do so was not an easy task.

We began by excavating the root systems of dozens of large red oaks so that we could inoculate roots with the oak wilt fungus to simulate root graft infections. These trees were treated with propiconazole (20ml Alamo® suspended in 1 liter of water per diameter inch) using a macroinfusion technique either two weeks before or two weeks after being inoculated. After our treatments were complete, we covered the root systems back up and waited. Over the next several years, the root systems were periodically re-excavated and we assessed where and in what concentrations propiconazole was present, what effect the treatment had on the incidence and survival of the oak wilt fungus, and what effects propiconazole had on the growth of treated trees. What we found was quite interesting, and has many implications for how propiconazole should be used for oak wilt control.

Did propiconazole move downward into the root system following macroinfusion?

Propiconazole is known to travel upward in the transpiration stream into the crown following injection. The oak wilt pathogen is most often transmitted through root grafts however, so we have often wondered if propiconazole also moves downward into the root system to provide below-ground protection. The answer is yes. In addition to high concentrations of the fungicide in the stem, propiconazole was also found in the root systems of all treated trees. We determined the concentration of propiconazole in the root system out to a minimum of three feet from the injection site. With few exceptions, we detected significant concentrations of the fungicide even at the furthest distances. Based on the concentrations we found however, it is unlikely that propiconazole is translocated throughout the entire root system and most likely does not prevent root graft spread.

What was the concentration of the fungicide in the root system?

The concentration of propiconazole varied considerably between roots, distance from the injection point, and the amount of time that had passed since the treatment was conducted. The concentration of the injected fungicide solution was approximately 3,050 ppm, while concentrations in the root samples ranged

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on average from 167 ppm (12 inches from the injection site after two months) to 7.7 ppm (3.5 feet from the injection site after two years). In laboratory tests using fungicide-amended culture plates, propiconazole kills the oak wilt fungus at less than one ten-thousandth of the concentrations we found.

Excavated red oak root systems.

Was propiconazole able to eradicate the fungus from the root system of a tree that was already infected?

No. In all of the trees injected with propiconazole after the fungus was introduced to the root system, we were able to find the fungus alive, most commonly in those portions of the root system with the lowest concentrations of the fungicide.

Was propiconazole able to prevent infection by the fungus when applied before the roots were inoculated?

If propiconazole was present in the roots at relatively high concentrations, how was the fungus able to survive there? The short answer is we don't know. Concentrations of a fungicide that work well in a lab do not necessarily have the same effectiveness in a tree. For the first year of the study, the fungus was only present in those roots with less than 30 ppm of propiconazole present. Fungicide concentrations greater than that appear to have been too toxic for the fungus to survive. But after two years, the fungus was found in roots with much higher concentrations of the fungicide. It is possible that after two years, the fungicide was compartmentalized in older tissue while the fungus was able to spread into new growth, thereby avoiding exposure to the chemical.

For this study, the root systems of large oaks were excavated using an Airspade®.

So if the fungus survived in propiconazole-treated trees, were the treatments effective?

Yes. Although the fungus was present in the root system of all of the oaks, none of the trees wilted within two years of the treatment application. Three years after treatment however, about 15% of the trees began to wilt and die. So although the treatments failed to prevent infection or eradicate the fungus, they did prevent disease development for more than two years.

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Alamo® macor-infusion fungicide treatment to protect red oaks from oak wilt.

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So how does propiconazole work?

It has long been known that the oak wilt fungus does not cause its host tree to wilt until it spreads from the roots into the stem and branches. Although propiconazole does not prevent infection of the root system, we think that high concentrations of the fungicide in the root crown zone and lower stem restrict the pathogen to the more distant portions of the roots where it can do little harm. This is known as a latent infection, or an infection without symptom development. Although propiconazole disappears from the tree canopy after a year, high residual concentrations of the fungicide in the lower stem and root crown can still be detected two or more years after treatment, providing multi-year protection. Propiconazole does not appear to be very effective in red oaks once symptom development has begun however.

Are re-treatments necessary?

Yes, it is recommended that trees be re-treated every two years. Previous studies have shown that after two years, the rate of disease incidence begins to increase without re-treatment. Our study showed that the concentration of propiconazole decreases by about 40% per year in roots. As the fungicide is degraded over time, the fungus may be able to spread from the roots and into the stem and branches within an individual tree to cause disease. Alternatively, if the fungicide is compartmentalized in older tissues, the fungus may be able to spread through new growth from the roots into the above-ground tissues. In both cases, re-treatment should prevent the oak wilt fungus from causing the disease. However, because propiconazole does not eradicate the fungus from a root system nor prevent infection, it is not known how many re-treatments will be necessary before the risk of disease subsides.

What are the effects of propiconazole on the tree?

Propiconazole itself has very low plant toxicity, and is therefore safe for repeated use on susceptible oaks. Injury sustained from the treatment process is mostly limited to the small holes drilled into the root flare or lower stem to inject the fungicide into the tree's vascular system. However, it has long been suspected that propiconazole may have other effects on the tree, some of which could be beneficial for disease prevention in addition to the fungicidal effects we already know about. During our investigation, we observed that propiconazole had effects on the growth and development of treated trees at microscopic levels. Reductions in earlywood and latewood production, vessel diameters, pit diameters, and the number of vessels produced per year were among some of the most interesting effects. Changes in growth lasted up to 5 years after treatment application. Because the fungus spreads through a tree's vascular system, these observed changes could inhibit the spread of the pathogen and its ability to cause disease, but more research is needed to understand these effects fully.

In conclusion, systemic fungicides such as propiconazole will continue to be a useful tool in the management of oak wilt on individual high value trees. By understanding how the fungicide is translocated in the tree and what effects it has on both the host and pathogen, we can better prescribe practical and effective treatments. Propiconazole by itself cannot prevent the spread of oak wilt through root grafts. Therefore, when possible, use of this fungicide should be coupled with root graft disruption and the other practices that are critical components of an integrated oak wilt management strategy.

(Note: Mention of trade names does not constitute endorsement by the U.S. Department of Agriculture. This project was funded by several sources: Tree Research and Education Endowment Fund, Rainbow Treecare Scientific Advancements, the U.S. Forest Service Pesticide Impact and Assessment Program, the U.S. Forest Service Northern Research Station, and the Minnesota Turf and Grounds Association.)