USDA United States Department of Agriculture

Forest Service

North Central Research Station

Research Note NC-390
2005

Evaluation of Propiconazole Operational Treatments of Oaks for Oak Wilt Control

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ABSTRACT.—Oaks commercially treated with propiconazole on 29 sites in Minnesota in 1998 were evaluated for efficacy in controlling oak wilt. Root graft spread occurred in 39 percent of preventively treated red oaks over 5 years; spread in white oaks occurred only once. Propiconazole generally prevented further disease symptom development in white oaks.

KEY WORDS: *Ceratocystis fagacearum*, oak wilt, propiconazole.

Oak wilt, caused by the fungus *Ceratocystis fagacearum* (Bretz) Hunt, affects oaks (*Quercus* spp.) in both the red (Lobatae) and white (Quercus) oak groups. Multiple species of both groups are common in urban and rural forested landscapes of the Midwestern United States. Following infection, red oaks wilt within weeks to months and die in the same or the next summer. In white oaks, infection causes scattered wilting of crown branches or major limb or fork dieback in one to several years. Death of white oaks does not usually occur until several years later.

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Oak wilt is a significant problem in both urban and suburban landscapes where trees are of higher value than those in forested settings. Increasing development of wooded areas in major urban centers of the Upper Midwest has led to increases in oak wilt (Juzwik and Schmidt 2000). Various oak wilt control tools and integrated oak wilt management regimes are used in such settings (Juzwik *et al*. 2004). One such tool is the fungicide propiconazole (PPZL).

The first studies involving intravascular injection of oaks with PPZL for oak wilt control were conducted in 1987 on live oaks (*Quercus virginiana* Mill. and *Q. fusiformis* Small) in Texas (Appel 2001). A few published studies exist on effective use of PPZL on oaks in the Northern United States (Johnson 2001, Nair 1995, Osterbauer and French 1992, Osterbauer *et al*. 1994). In the Northern States, current operational use of PPZL by commercial arborists is based on observation and experience, as well as on these published reports. Arborists desire documentation of their operational treatments to either test or validate their application practices for PPZL.

In 1998, evaluation studies of operational treatments of red and white oaks in the Minneapolis-St. Paul, Minnesota, metropolitan area began in a cooperative effort of the USDA Forest Service and a local arboricultural research company. The objectives of the 5-year project were to 1) evaluate efficacy of operational PPZL treatments of oaks used in an effort to prevent belowground spread of *C. fagacearum* from wilting red oak(s) to healthy red oaks; 2) evaluate efficacy of PPZL operational treatments of bur (*Quercus macrocarpa* Michx.) and white oak (*Quercus alba* L.) for preventive treatment as in 1; and 3) evaluate efficacy of therapeutic, operational treatments of bur and white oaks with PPZL. This observational study involved re-visiting treatment sites

three times over 5 years to determine long-term efficacy of PPZL in controlling oak wilt. No controls were included in this evaluation study.

MATERIALS AND METHODS

Study Area and Trees

The trees monitored in these studies were located on 29 sites in 20 suburbs surrounding the Minneapolis—St. Paul, Minnesota, area. The trees were commercially treated by the cooperating arboricultural company for clients requesting the service. Treated species of the red oak group were northern red oak (*Quercus rubra* L.) and northern pin oak (*Q. ellipsoidalis* Hill). Treated species of the white oak group were bur oak and white oak.

Study Design

Three related studies were defined based on the intended purpose of the chemical treatment. In the red oak preventive study, operational treatment was intended to protect apparently healthy red oaks located within root grafting distance of recently wilted red oaks from developing oak wilt symptoms. The intent of operational treatment in the white oak preventive study was similar, except the treated trees and the nearby *C. fagacearum*-infected trees exhibiting active wilt were bur and/or white oaks. In the white oak therapeutic study, all white and bur oaks on a site diagnosed with oak wilt were treated with PPZL. Diagnosis of oak wilt was based on visual presence of symptomatic foliage or crown wilting and, in some cases, laboratory isolation of the pathogen. The extent of wilting in the crowns of affected oaks ranged from 5 to 50 percent at the time of PPZL treatment.

Treatment

All study trees were injected with PPZL at the standard lower rate stated on the product label (Novartis Crop Protection, Greensboro, NC): 10 ml product (1.4 g a.i or .045 oz.) per 2.5 cm (1 in.) diameter of main tree stem at 1.4 m (4 ft) height added to the appropriate amount of water (1.0 liter water for each 10 ml of PPZL). Established protocols for macro-infusion were followed (Prosser *et al*. not dated). At least four crews, each consisting of two technicians and one crew leader, performed the injections. A total of 14 individuals were assigned to the various crews during the treatment period. In the spring before treatment, all crews received training in standard PPZL macro-infusion techniques. The trees were treated between June 17 and September 28, 1998, which corresponded to the period between full leaf expansion (late spring) and onset of fall coloration. In the therapeutic white oak study in subsequent years, selective pruning was performed on the treated trees during winter to remove dead wood from the tree crowns.

Data Collection and Tree Condition Assessment

Diameter of the tree stem at 1.4 m height (diameter at breast height – d.b.h.) was recorded for each treated tree at the time of PPZL injection. In the two preventive studies, the distance between each treated tree and the nearest oak with wilt symptoms was also determined and recorded. The crown condition of each tree was assessed at the time of PPZL treatment in 1998 and once during the summer in 1999 (first year), in 2000 (second year), and in 2003 (fifth year) after treatment. The arborist firm developed a rating system, which determined a score for each of the following categories: characteristics of crown development, trunk quality, branch structure, twig growth rate, foliage color, incidence of insect and disease organism damage or presence, and evidence of visible root problems. The possible values of the rating system ranged from 5 (indicating best condition) to 0 (poorest condition) for each category. These individual scores were then added to produce an overall condition index for each tree, with 35 being the maximum value possible. Extent of crown wilt present in the tree crown was estimated separately. The percentage of wilt observed in the crown, as determined from four different locations around the tree (cardinal directions), was recorded once each summer during 1999, 2000, and 2003. In cases where landowners removed trees that died in subsequent years, the year of tree death and year of removal were recorded for each. Red oaks that developed > 60 percent wilt in the last year of this study were considered dead in the data summarization.

RESULTS

Red Oak Preventive Study

The 46 PPZL-treated red oaks ranged in size from 13 to 89 cm (5 to 35 in.) d.b.h. They were located from 4.6 to 15.2 m (15 to 50 ft) from the nearest *C. fagacearum*-infected

tree. Oak wilt was first observed in the treated trees in 1999 when one (2%) began wilting late in the growing season and died the following year (table 1). An additional 17 trees (37%) wilted between early September 2000 and late August 2003. Three of these were observed with active wilt in 2003. Mortality due to *C. fagacearum* was higher in trees ≤ 9 m (30 ft) from previously wilted trees compared to treated trees between 9 and 15 m (50 ft) from the nearest pathogen-killed tree (P = 0.08). Of the 18 trees that died over the 5 years, 13 (72%) were less than 9 m (30 ft) from the nearest *C. fagacearum*-killed tree in 1998 when PPZL was injected. Tree mortality due to *C. fagacearum* was also higher (44%, or 8 of 18 trees) in larger diameter trees (d.b.h. > 48 cm or 19 in.) (P = 0.10). The remaining live trees showed no change to slight improvement in tree condition when ratings between 2003 and 1998 were compared.

White Oak Preventive Study

The 26 PPZL-treated white and bur oaks ranged in size from 14 to 89 cm (6 to 34 in.) d.b.h. They were located from 0.6 to 13.7 m (2 to 45 ft) from the nearest *C. fagacearum*-infected white or bur oak. Only one tree (a white oak) exhibited oak wilt symptoms over the 5-year period, and none died. A few symptomatic branches (< 10% of the crown) were observed on the one affected tree in 1999 and 2000, but no new symptoms were observed in 2003. The condition index for all of the other trees did not change appreciably over the 5-year period.

White Oak Therapeutic Study

The eight bur oaks injected with PPZL ranged in size from 42 to 86 cm (17 to 34 in.) d.b.h. The initial percentages of tree crowns exhibiting wilt symptoms ranged from 5 to 30 (table 2). During the 5-year period, only one tree exhibited new oak wilt symptoms (5% increase) and this occurred only in 2000. The tree was injected with PPZL again in 2000 and dead branches were removed; no evidence of new wilt was found in 2003. Dead branches were pruned from tree crowns during winters in subsequent years after injection. Dead branch pruning of the tree crowns in 1998 resulted in slightly decreased (< 1%) crown size (table 2). Tree condition index over the 5 years differed by tree size. The index slightly decreased for bur oaks ≤ 56 cm (22 in.) d.b.h., but increased for those > 56 cm.

The 13 white oaks (*Q. alba*) treated with PPZL ranged in size from 25 to 69 cm (12 to 27 in.) d.b.h. The initial percentages of tree crowns exhibiting wilt symptoms ranged from 5 to 45 (table 2). Of eight oaks ≤ 56 cm (22 in.) d.b.h., one exhibited new oak wilt symptoms in 1999, but none of the trees exhibited symptoms in 2000 and

Table 1.—*Mortality observed in red oaks operationally treated with propiconazole in 1998 for prevention of root graft spread of* Ceratocystis fagacearum

Distance to diseased tree (m)	Tree diameter (cm)	No. treated trees	Tree mortality by year				Cumulative mortality (5 yrs)	
			1998[1]	1999	2000	2001-2003	Number	Percent
≤ 9	≤ 33	11	0	0	0	4	4	36
	> 33 to 48.3	5	0	0	0	3	3	60
	> 48.3	10	0	0[2]	1	5	6	60
> 9 to 15	<33.02	9	0	0	0	2	2	22
	> 33 to 48.3	7	0	0	0	1	1	14
	> 48.3	4	0	0	0	2	2	50
Total		46	0	0	1	17	18	39

[1]Year trees were treated.

[2] Wilting crown observed late in growing season, but did not result in mortality in 1999.

Table 2.—*Incidence and extent of crown wilting in operationally treated bur and white oaks infected with* Ceratocystis fagacearum *prior to and following propiconazole treatment*

Oak species	D.b.h. (cm)	No. trees evaluated	Intitial percent wilt (1998)		Trees exhibiting new crown wilt			Cumulative percent of crown removed by 2003	
			Average	Range	Year	Number	Crown wilt (percent)	Average	Range
Bur	42-86	8	16	5-30	1999	0	0	16	5-30
					2000	1	5	17	5-30
					2001-2003	0	0	17	5-30
White	< 56	8	14	5-35	1999	1	5	14	5-35
					2000	0	0	14	5-35
					2001-2003	0	0	14	5-35
	≥ 56	5	21	5-45	1999	1	25	26	5-45
					2000	2	5, 5	28	5-50
					2001-2003	0	0	28	5-50

2003. Of five trees > 56 cm d.b.h., one tree had new wilt in 1999 and two had new wilt in 2000. Pruning of wilting and other dead branches from tree crowns resulted in a slight (2%) reduction in crown size. Tree condition index over the 5 years differed by tree size. The index slightly decreased for white oaks ≤ 56 cm (22 in.) d.b.h., but slightly increased for those >56 cm.

DISCUSSION

Red Oak Preventive Treatment

The observed 100-percent survival rate of red oaks over 2 years and the 61-percent survival rate over the total 5 years of this study suggest that preventive macro-infusion treatments with the PPZL product at 1.4 g a.i./ 2.54 cm d.b.h. (0.045 oz/1 in.) provides limited suppression of oak wilt spread via root grafts. It appears that the ability of the chemical treatment to suppress disease progression decreases over time (years). Many factors likely influence efficacy of PPZL in preventing root graft spread of the pathogen. Such factors include distances over which root grafts can be expected, frequency of root graft transmission, rapidity with which *C. fagacearum* moves through connected root systems, longevity of PPZL activity in trees, and PPZL application rate.

Root graft transmission of the oak wilt pathogen to healthy oaks commonly occurs within 15 m (50 ft) of a diseased oak of the same species. Heimlick and Fox (1961) reported pathogen spread and subsequent death in trees up to 15 m (50 ft) from a disease source. In another study in which trees were injected with radioisotopes, radioisotopes were detected in trees up to ~15 m (50 ft) from the injected tree, presumably translocated between trees through root grafts (Kuntz and Riker 1955). The rate of spread of oak wilt through root grafts, especially in red oaks, can be as much as 12 m (40 ft) per year (Bruhn *et al*. 1991). In our study, all preventively treated red oaks were less than 15 m (50 ft) from diseased trees and thus had a high probability of becoming infected with *C. fagacearum* within several years after the death of the adjacent oak wilt-killed tree.

The length of time required for transmission of the fungus from infected to adjacent healthy trees varies. By some accounts the transmission from an oak wilt-killed tree to a healthy tree via root grafted roots is rapid due to the loss of upward vascular movement caused by vascular plugging in the diseased tree (Menges and Kuntz 1985). However, Himelick and Fox (1961) found that while the majority of oak wilt centers remained active year after year, a few other centers remained dormant for up to 6 years and then re-activated, i.e., newly wilted trees were observed. With such a wide time span over which transmission may occur, it is possible that the pathogen can spread after the PPZL is degraded or no longer active in a treated tree. Osterbauer and French (1992) injected trees with PPZL at a rate of 0.43 g a.i./ 2.54 cm d.b.h. (0.014 oz / in.). They were able to detect the PPZL activity at 1, 2, 8, and 12 months after injection, but not 20 or 23 months after injection. Comparing these earlier results to our study suggests that re-treatment with PPZL two growing seasons after initial treatment may be beneficial. For example, if a tree is treated in year 1, re-treatment would seem appropriate just before fall leaf coloration of year 2, or soon after full leaf expansion in year 3.

Chemical application rate is an additional factor to consider. Red oaks injected with 0.42, 0.56, 0.7, and 0.84 g PPZL / 2.54 cm d.b.h. (0.015, 0.020, 0.024, and 0.030 oz / in.) to prevent root graft transmission of the pathogen had a combined survival rate of 100 percent at < 14 months and 76 percent at 24 months (Johnson 2001). Trees treated with the highest rate (0.84 g PPZL / 2.54 cm d.b.h.) had a 95-percent survival rate after 2 years. Results of our study can be compared to those of Johnson (2001). Treatment with PPZL at 0.84 g a.i. / 2.54 cm d.b.h. (Johnson 2001) is as successful over a 2-year period as 1.4 g a.i./ 2.54 cm d.b.h. (0.045 oz /1 in.) (our study), while lower rates (Johnson 2001) had lower success rate in preventing wilt 2 years after injection. Perhaps increasing the application rate may lengthen the time of disease suppression.

White and Bur Oak Preventive Treatments

Preventive treatment of white and bur oaks with PPZL has been proven to be very effective in protecting these trees from oak wilt symptom development, perhaps by preventing pathogen spread of *C. fagacearum* through root grafts. Although preventive treatment is effective, the current viewpoint of arborists is to not treat preventively due to the observed success of operational therapeutic treatments. An arborist will usually not treat a white or bur oak unless the tree is in an area where disease pressure and aesthetic value are very high and/or the client requests treatment.

White and Bur Oak Therapeutic Treatments

PPZL applications provided very good control of oak wilt in white and bur oaks already infected at time of treatment. This finding supports the commonly recommended treatment of these species. Although preventive treatment of white and bur oaks at high risk for oak wilt is valid, therapeutic treatment of infected white and bur oaks, when done promptly, arrests disease progression with minimal crown loss. In a previous study, trees with up to 50-percent affected crown were successfully treated with PPZL (Osterbauer 1991, Osterbauer *et al*. 1994).

Concluding Remarks

Results of our studies provide valuable documentation on the efficacy of PPZL in operational preventive treatment of red and white oaks and in therapeutic treatment of white oaks. However, further studies with untreated controls and randomly assigned treatments are needed to provide additional efficacy information on preventive treatments particularly for red oak species. Such studies are currently underway at the University of Minnesota and at the North Central Research Station, USDA Forest Service.

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