Biology and Control of Lemon Tree Wood Rot Diseases1[1]

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Abstract

Brown heartwood rot is commonly found in mature lemon groves in southwestern Arizona. Two basidiomycete fungi, Antrodia sinuosa and Coniophora eremophila, have been isolated from symptomatic trees. A major difference between the two pathogens is that Antrodia forms spore-producing fruiting bodies on infected wood within lemon groves, whereas fruiting on lemon wood infected by Coniophora has not been observed. A third fungus, a species of Nodulisporium, recently was recovered from small dead lemon tree branches with an internal white wood rot. Experiments were conducted to compare the severity of wood rot caused by each of these pathogens. The highest rates of wood decay for each pathogen occurred from May through October, when the mean length of wood decay columns for Antrodia, Coniophora and Nodulisporium was 183, 94 and 146 mm, respectively, and the mean air temperature was 29°C. In comparison, the mean length of wood decay columns from November through April for the same pathogens was 35, 18 and 38 mm, respectively, with a mean air temperature of 17°C. When inoculated with Antrodia, Coniophora or Nodulisporium, the length of wood decay columns on 40-mm-diameter branches was 26, 38 and 24% larger, respectively, compared to wood decay on 10-mm-diameter branches. The length of wood decay columns on inoculated Lisbon lemon was always numerically greater than that on tested orange, grapefruit and tangelo trees. Compared to lemon, wood decay columns ranged from 45 (on grapefruit) to 62 %(on orange) shorter when inoculated with Antrodia, 52 (on orange) to 59% (on tangelo) for Coniophora and 20 (on tangelo) to 51% (on grapefruit) for Nodulisporium. Compared to non-treated branches, suppression of wood decay in the presence of a test fungicide ranged from 28 to 79% for Antrodia, 77 to 91% for Coniophora and 71 to 92% for Nodulisporium. For each pathogen, the lowest numerical degree of wood rot suppression occurred in the presence of trifloxystrobin (Flint), whereas the highest level of suppression was observed with propiconazole (Break). On greasewood, mesquite, Palo Verde and salt cedar, the length of wood decay columns ranged from 20 to 60 mm when inoculated with Antrodia, 1 to 63 mm for Coniophora and 24 to 90 mm for Nodulisporium. For all three wood-rotting fungi, resultant wood decay columns were always much greater on lemon compared to tested desert-dwelling plants. Current disease management strategies include minimizing branch fractures and other non-pruning wounds as well as periodic inspection of trees and removal of infected branches, including physical removal of all wood infected with Antrodia from the grove site.

1 The authors wish to sincerely thank the Arizona Citrus Research Council for supporting this project. This is the final report for project 2001-07 "Biology and Control of Lemon Tree Wood Rot Diseases".

This is a part of 2002 Citrus and Deciduous Fruit and Nut Research Report, the University of Arizona College of Agriculture and Life Sciences, index at http://ag.arizona.edu/pubs/crops/az1303

Introduction

In 1992, a species of *Coniophora* was first reported to be associated with a brown heartwood rot in lemon trees in southwestern Arizona. The wood decay had been observed in lemon plantings in this region for at least 30 years, but the cause was previously unknown. Subsequent research revealed the identity of this basidiomycete to be *Coniophora eremophila*, the only species of *Coniophora* known to occur in the Sonoran desert region of Arizona and Mexico. During surveys of mature orchards to determine the incidence of lemon trees infected with *Coniophora*, a second basidiomycete fungus was isolated from symptomatic decayed wood. This fungus subsequently was identified as *Antrodia sinuosa*. *Coniophora eremophila* is primarily a saprobe on dead fallen wood on a number of species of desert trees, shrubs, and cacti. There are no reports of *Antrodia sinuosa* causing decay of heartwood in living hardwoods. Similarities between the two pathogens include the following: each fungus grows optimally at 30 to 35°C, neither organism produces a fleshy fruiting body, they colonize lemon trees primarily through branch fractures and other non-pruning wounds, and both cause a brown wood rot in infected trees. A major difference between the two pathogens is that *Antrodia* forms spore-producing fruiting bodies on infected wood within lemon groves, whereas fruiting on lemon wood infected by *Coniophora* has not been observed.

In 1999 a third fungus was recovered from small dead lemon tree branches in Yuma. Unlike the brown wood decay from which *Antrodia* and *Coniophora* were recovered, this fungus was isolated from decayed wood that was white in color. This third fungus subsequently was identified as a species of *Nodulisporium.*

The objectives of this research project were to study the effect of season (ambient temperature) on the rate of wood decay, examine the rate of wood decay on branches of differing diameters, compare the ability of each wood decay fungus to cause wood rot on different types of citrus trees, evaluate potential fungicides for disease control, and test the ability of each pathogen to cause wood decay in some desert plants that grow in southwestern Arizona.

Materials and Methods

All studies involved the actual inoculation of citrus tree branches (or in one test branches of selected desert plants) followed by measurement of resultant wood decay columns at a given time after inoculation. To prepare inoculum, 8-mm-diameter x 13-mm-long autoclaved wood dowel pieces were placed on mycelium of *Antrodia*, *Coniophora* or *Nodulisporium* growing in plastic Petri plates containing potato dextrose agar, then incubated for 1 month in the dark at 28°C. Each test plant was inoculated by placing one dowel segment containing one of the pathogens into a 9-mm-diameter x 26-mm-long hole in the branch. Shorter holes and inoculum dowel segments were used when branches were less than 30 mm in diameter. The dowel segment containing the pathogen was positioned and retained in the bottom of each inoculation hole by driving another dowel piece not containing the pathogen into each wound. This longer dowel piece was cut off flush with the surface of the branch and the wound was sealed with paraffin. Disease development usually was assessed approximately 6 months later (except for the seasonal study when branches were harvested 3 months after inoculation) by removing inoculated branches, splitting them in half, and measuring the length of the resultant decay columns. Inoculated branches ranged from 6 to 8 cm in diameter, except in the lemon branch diameter study. In the fungicide trial, the inoculation hole in each branch was filled with a test fungicide, and then the dowel segment containing one of the pathogens was coated with the same compound before placement into the inoculation hole. The second dowel segment used to retain the colonized dowel piece in the inoculation hole also was treated with the same fungicide. Each treatment within a field study was replicated at least seven times and each trial was established in a randomized complete-block design.

Results and Discussion

The highest rates of wood decay for each pathogen occurred from May through October (Table 1), when the mean length of wood decay column for *Antrodia*, *Coniophora* and *Nodulisporium* was 183, 94 and 146 mm, respectively, and the mean air temperature was 29°C. In comparison, the mean length of wood decay columns from November through April for the same pathogens was 35, 18 and 38 mm, respectively, with a mean air temperature of 17°C. When inoculated with

Antrodia, *Coniophora* or *Nodulisporium*, the length of wood decay columns on 40-mm-diameter branches was 26, 38 and 24% larger, respectively, compared to wood decay on 10-mm-diameter branches (Table 2). The length of wood decay columns on inoculated Lisbon lemon was always numerically greater than that on tested orange, grapefruit and tangelo trees. Compared to lemon, wood decay columns ranged from 45 (on grapefruit) to 62 % (on orange) shorter when inoculated with *Antrodia*, 52 (on orange) to 59% (on tangelo) for *Coniophora* and 20 (on tangelo) to 51% (on grapefruit) for *Nodulisporium* (Table 3). Compared to non-treated branches, suppression of wood decay in the presence of a test fungicide ranged from 28 to 79% for *Antrodia*, 77 to 91% for *Coniophora* and 71 to 92% for *Nodulisporium* (Table 4). For each pathogen, the lowest numerical degree of wood rot suppression occurred in the presence of trifloxystrobin (Flint), whereas the highest level of suppression was observed with propiconazole (Break). On greasewood, mesquite, Palo Verde and salt cedar, the length of wood decay columns ranged from 20 to 60 mm when inoculated with *Antrodia,* 1 to 63 mm for *Coniophora* and 24 to 90 mm for *Nodulisporium* (Table 5). For all three wood-rotting fungi, resultant wood decay columns were always much greater on lemon compared to tested desert-dwelling plants.

Loss of branches and ultimately trees due to wood rot is a continuing concern for lemon producers in southwestern Arizona and southeastern California. Since *Antrodia*, *Coniophora* and *Nodulisporium* primarily colonize lemon trees at branch fracture sites and other non-pruning wounds, minimizing limb breakage and other non-pruning wounds should significantly reduce new infections. Citrus groves should be inspected at least annually and any infected sections of branches should be removed promptly. Since *Antrodia* can sporulate on infected lemon wood on the tree or on old infected wood pieces on the grove floor, it is important to remove all infected wood from the grove site. No fungicides are currently registered for control of this disease; however, experimental data from this research suggests that preventative treatment of wounds with selected fungicides could reduce subsequent development of wood rot.

Table 1. Seasonal changes in severity of wood rot.

Time period	Length of wood decay column in mm *		
	Antrodia	*Coniophora*	*Nodulisporium*
February to April	58	23	60
May to July	192	56	150
August to October	174	133	142
November to January	12	13	17

* Average values for two years.

Table 2. Wood decay on branches of different diameters.

Branch diameter in mm	Length of wood decay column in mm *		
	Antrodia	*Coniophora*	*Nodulisporium*
10	112	30	86
20	121	36	105
40	151	48	114

* Average values from two trials.

Table 3. Wood decay on different kinds of citrus.

Type of citrus	Length of wood decay column in mm *		
	Antrodia	*Coniophora*	*Nodulisporium*
Lisbon lemon	214	121	152
Valencia orange	82	38	118
Marsh grapefruit	118	53	74
Orlando tangelo	96	50	121

* Average values from two trials.

Table 4. Effects of fungicides on wood rot development.

	Length of wood decay column in mm *		
	Antrodia	*Coniophora*	*Nodulisporium*
Propiconazole (Break)	32	10	12
Azoxystrobin (Abound)	44	12	16
Pyraclostrobin (Headline)	72	19	22
Kresoxim-methyl (Sovran)	81	25	41
Trifloxystrobin (Flint)	108	20	42
Non-treated control	150	110	144

* Average values from two trials.

Table 5. Wood rot on some desert-dwelling plants compared to lemon.

Type of citrus	Length of wood decay column in mm *		
	Antrodia	*Coniophora*	*Nodulisporium*
Palo Verde	28	16	24
Salt cedar	38	63	90
Greasewood	20	1	31
Mesquite	60	44	73
Lisbon lemon	182	116	148

* Average values from two trials.