# Biology and Control of *Coniophora eremophila* on Lemon Trees in Arizona

**D. M. Bigelow,** Research Specialist, Department of Plant Pathology, University of Arizona, Tucson 85721; **M. E. Matheron,** Extension Plant Pathologist, Department of Plant Pathology, University of Arizona, Yuma 85364; and **R. L. Gilbertson,** Professor, Department of Plant Pathology, University of Arizona, Tucson 85721

**ABSTRACT**

Bigelow, D. M., Matheron, M. E., and Gilbertson, R. L. 1996. Biology and control of *Coniophora eremophila* on lemon trees in Arizona. Plant Dis. 80:934-939.

A survey of mature lemon trees showed an average of 30% of trees with symptoms of brown heartrot caused by *Coniophora eremophila*. Growth of *C. eremophila* inoculated into branches of Valencia orange, Marsh grapefruit, Orlando tangelo, or Lisbon lemon on rough lemon rootstock was significantly higher in lemon than in other types of citrus. *C. eremophila* inoculated into Lisbon lemon branches on trees established on rough lemon, volkameriana, macrophylla, Cleopatra mandarin, sour orange, or Troyer citrange rootstocks showed no significant differences in growth. Somatic incompatibility tests of isolates from one mature orchard demonstrated that isolates from different trees were incompatible. In vitro fungicide trials showed that NECTEC P paste and NECTEC blank paste effectively reduced decay on lemon blocks 15 weeks after inoculation with *C. eremophila*. Field fungicide trials showed that NECTEC P paste with fungicides, as well as the blank paste without fungicides, significantly inhibited the advance of the fungus 7 months after inoculation. Also, propiconazole at 10,000 µg/ml, imazalil at 20,000 µg/ml, or propiconazole at 10,000 µg/ml in combination with imazalil at 20,000 µg/ml significantly inhibited the advance of the fungus.

In 1992, a *Coniophora* species was first reported to be associated with a brown heartwood rot in lemon trees in Yuma, Arizona (20). This decay had been a serious problem in lemon for at least 30 years. It was the first report of a *Coniophora* species causing heartwood decay in living citrus or any other fruit trees. Surveyed mature orchards have a high percentage of lemon trees with visible brown heartwood rot (Fig. 1A). This decay is associated with a progressive dieback and decline and reduction of fruit production in infected trees. Growers consider this to be the most important disease in lemon orchards in the Yuma region.

In Arizona, lemons were harvested from 6,520 ha in the 1993 to 1994 season, 5,880 ha of that from Yuma County and the remainder from Maricopa County (23). Although the brown rot occurs in Maricopa County, the problem is not considered to be serious in orchards in this region.

The only known *Coniophora* species in the Sonoran desert region, *Coniophora eremophila* Lindsey & R. L. Gilbertson, was described in 1975 (19). It has been found fruiting on a number of species of desert trees, shrubs, and cacti, mainly as a saprobe on dead fallen wood and associated with a brown rot (12–14). Sonoran desert substrates on which *C. eremophila* have been recorded include ironwood (*Olneya tesota* A. Gray), desert-willow (*Chilopsis linearis* (Cav.) Sweet), saguaro (*Carnegiea gigantea* (Engelm.) Britton & J. Rose), Arizona black walnut (*Juglans major* (Torr.) A. Heller), point-leaf manzanita (*Arctostaphylos pungens* H.B.K.), velvet ash (*Fraxinus velutina* Torr.), jumping cholla (*Opuntia fulgida* Engelm.), Mexican elder (*Sambucus mexicana* K. Presl ex DC.), velvet mesquite (*Prosopis velutina* Woot.), and oneseed juniper (*Juniperus monosperma* (Engelm.) Sarg.) from New Mexico. An isolate from brown rot in a recently fallen saguaro also has the characteristics of a *Coniophora* and is identical to isolates from lemon. The cultural morphology of *Coniophora* is unique at the genus level but it is difficult or impossible to differentiate *Coniophora* species in culture (15,27). No fruiting bodies have been found associated with the disease in lemon.

The latest monograph on *Coniophora* recognizes 12 species (15). Only four species are known to occur in Arizona (9,10, 13,14,16). The three species other than *C. eremophila* occur in conifer forest ecosystems at higher elevations in Arizona. The only other record for *C. eremophila* was reported by Ginns (15) from Chile and occurred on dead wood of unknown identity.

Most of the 12 *Coniophora* species in North America are not known to cause decay on living trees. Three species other than *C. eremophila*—*C. puteana* (Schumach.:Fr.) P. Karst., *C. olivacea* (Pers.:Fr.) P. Karst., and *C. fusispora* (Cooke & Ellis) Sacc.—are reported to cause decay in living trees (11,15,16). These three species cause root and butt rots and are not known to cause decay in upper trunks and branches. Since no other *Coniophora* species have ever been found in the Sonoran Desert, we conclude that the *Coniophora* causing the common brown heartrot in lemon is *C. eremophila*.

The plant disease clinic database at the University of Arizona Department of Plant Pathology has records of diseased plants brought into the clinic from 1920 through 1989, when the clinic closed. Of the 467 citrus entries listed there are no disease problems recorded in which fungi directly affected heartwood (21).

Collections listed in the database from the Arizona Mycological Herbarium at the University of Arizona, Tucson, have only 14 entries of wood decay fungi associated with citrus. The only brown rot fungus (five records) reported on citrus is *Amylosporus campbellii* (Berk.) Ryvarden (as *Tyromyces graminicola* Murrill) (14). This is a root- and butt-rot fungus and is not known to cause decay in trunks and branches as does *C. eremophila*.

In the literature on citrus diseases, no heartwood rot fungi were identified (3,7,8, 17,18,24,28). The APS compendium of citrus diseases (28) lists six diseases associated with living wood and involving fungal pathogens. The only wood decay fungi included cause white rots. Other reported diseases in citrus include a root rot in Florida caused by *Clitocybe tabescens* Bres. (18,29), a wood rot caused by *Ganoderma* in Florida (6), a root rot in California and Australia caused by *Armillaria mellea* (Vahl:Fr.) P. Kumm. (5,22), and a butt rot in grapefruit in Texas caused by *Ganoderma lucidum* (Curtis:Fr.) P. Karst. (25,26). *G. lucidum* is known to occur on lemon in the Yuma area, but apparently is not an important pathogen there.

The objectives of this research were to (i) determine the extent of brown heartwood rot in mature lemon orchards in Arizona, (ii) determine the relative susceptibility of various types of citrus, (iii) evaluate the possible effect of different rootstocks on brown heartrot development in Lisbon lemon, and (iv) explore potential chemical control of the disease.

## MATERIALS AND METHODS

**Field survey.** Orchards were surveyed in 1993 to determine the extent of heartwood rot in mature trees (29 to 31 years old). Trees with *C. eremophila* heartrot are generally easily distinguished by the pres-

Corresponding author: D. M. Bigelow
E-mail: dbigelow@ag.arizona.edu

Accepted for publication 13 May 1996.

Publication no. D-1996-0606-04R

ence of conspicuous brown rot decay columns exposed by pruning wounds, and broken or split branches (Fig. 1). These criteria were used for field identification of infected trees. A sample of 25 consecutive trees per orchard was selected in 11 different orchards throughout the Yuma area. Trees were scored as follows: (0), no disease symptoms; (I), symptomatic, disease symptoms including visible typical *C. eremophila* decay columns present; (II), questionable for symptoms, symptomatic, decline and dieback symptoms present but typical *C. eremophila* decay columns not visible; and (Dead), trees dead but cause of death could not be determined.

**Effect of citrus type and rootstock on disease development.** Branches ranging from 6 to 10 cm in diameter on 20- to 25-year-old Valencia sweet orange (*Citrus sinensis* (L.) Osbeck), Marsh grapefruit (*C.* × *paradisi* Macfady), Orlando tangelo (*C. reticulata* Blanco × *C. paradisi* Macfady), and Lisbon lemon (*C. limon* (L.) N. L. Burm.) trees established on rough lemon (*C. jambhiri* Lush.) rootstock were used in studies to determine the relative susceptibility of different types of citrus to *C. eremophila*. To prepare inoculum, autoclaved pieces of 8-mm-diameter × 13-mm-long wood dowel were placed on mycelia of an isolate (Y-1) of *C. eremophila* growing in 100 × 15 mm plastic petri dishes containing potato dextrose agar (PDA) and incubated for 1 month in the dark at 28°C. This isolate was derived from a lemon tree in Yuma County. Test trees were inoculated by placing one dowel segment containing *C. eremophila* into a 9-mm-diameter × 26-mm-long hole in a series of branches on several trees. The dowel segment containing the pathogen was positioned and retained in the bottom of each inoculation hole by driving another dowel piece not containing *C. eremophila* into each wound (Fig. 1B). This longer dowel piece was cut off flush with the surface of the branch and the wound was sealed with melted paraffin. Disease development was assessed 10 months later by removing infected branches, splitting them in half, and measuring the length of resultant decay columns. For each type of citrus, one branch on each of eight different trees was inoculated for the 1993 and 1994 trial. Control trees received dowel pieces that did not contain *C. eremophila*.

To evaluate the effect of rootstock on development of *C. eremophila*, branches ranging from 6 to 10 cm in diameter were inoculated on 20-year-old Lisbon lemon trees established on rough lemon, Volkamer lemon (commonly referred to as volkameriana, *C. volkameriana* (Pasq.) Tan.), alemow (commonly referred to as macrophylla, *C. macrophylla* P. J. Wester), Cleopatra mandarin (*C. reshni* Hort. ex Tan.), sour orange (*C. aurantium* L.), or Troyer citrange (*C. sinensis* × *Poncirus trifoliata* (L.) Raf.). Inoculation procedures for this study were identical to those described above. One branch on each of eight different trees established on each tested rootstock was inoculated for each of two runs of this experiment. Values obtained from each execution of an experiment were analyzed by analysis of variance (ANOVA) using the SigmaStat statistical software package (Jandel Scientific, San Rafael, CA). The Waller-Duncan *k*-ratio *t* test (least significant difference) was used to compare treatment means.

**Pairings in culture.** Presumptive heterokaryotic isolates obtained from decayed branches in one mature lemon orchard with a high percentage of symptoms were cultured and paired in all possible combinations on malt extract agar (MEA) (2% malt, 1.5% agar) by taking two cores from actively growing cultures and placing them approximately 1 cm apart in 60 × 15 mm petri dishes. Nine isolates designated A-1, A-2 (isolated from the same symptomatic branch of one lemon tree), G, J, K-1, K-2 (K-1 and K-2 from the same symptomatic branch of another lemon tree), and MD, N, and P from other trees were used. Self-paired isolates served as controls and all pairings were done at least twice. Mycelial interactions of paired isolates were noted 2 weeks after inoculation.

**Fungicide studies: in vitro experiments.** The effects of the following fungicides on mycelial growth were examined: fosetyl-Al (Aliette 80WDG, Rhone-Poulenc Ag Co., Research Triangle Park, NC); CGA-173506 50WP (Ciba-Geigy Corp., Greensboro, NC); and imazalil (97.5% technical grade) and propiconazole (91% technical grade) (both from Janssen Pharmaceutica, Inc., Piscataway, NJ). Various concentrations of fosetyl-Al and CGA-173506 were prepared in sterile distilled water, while imazalil and propiconazole were prepared in 95% ethanol, then added into autoclaved Difco corn meal agar (CMA) cooled to 50 to 55°C. The medium was thoroughly mixed after addition of the fungicide, then 10 ml was dispensed into a series of 60 × 15 mm plastic petri dishes. Final concentrations of each fungicide in the agar medium were 0.1, 0.5, 1, 5, 10, 50, and 100 µg/ml. Control dishes contained CMA alone. One isolate of *C. eremophila* from Yuma County (Y-1) and one isolate from Maricopa County (M-1)

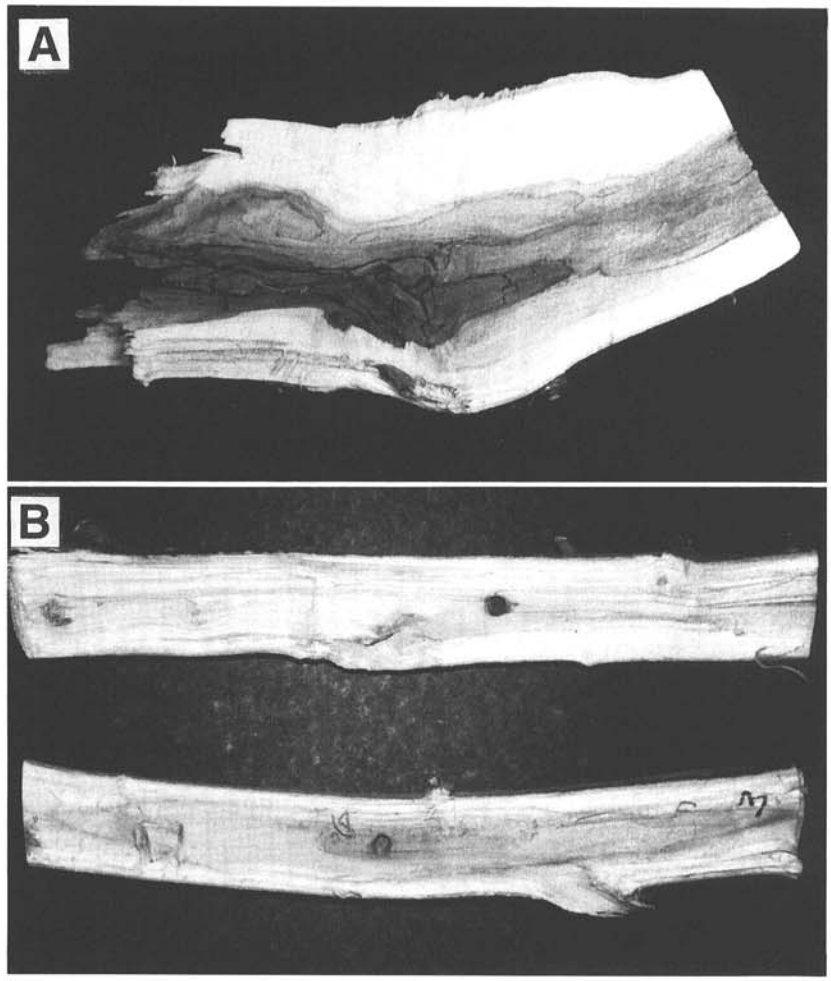


**Fig. 1.** Wood decay symptoms of brown heartwood rot caused by *Coniophora eremophila*. **(A)** Longitudinal section of lemon branch with natural infestation from mature orchard, showing early and advanced stages of brown rot. **(B)** Inoculated lemon branches after 10 months: upper, control (dowel only); lower, inoculated with a dowel infested with *C. eremophila*.

were used. A 6-mm-diameter agar disk from the margins of an actively growing colony of isolate Y-1 or M-1 was placed on the edge of each dish. Five days after incubation at 34°C, radial growth was measured. Each treatment contained 10 replicates, five with isolate Y-1 and five with isolate M-1. This test was performed twice.

To test fungicidal effects of these materials in lemon wood in vitro, the four fungicides and a wound dressing treatment, NECTEC P paint-like paste (formulation: 10,000 µg of propiconazole and 20,000 µg of imazalil per ml) were applied to lemon wood blocks and placed in chambers with one of two different isolates of *C. eremophila*. The lemon blocks were prepared following the American Society for Testing and Materials (ASTM) procedure for evaluating wood preservatives (2). They were oven dried at 93°C for 3 days, then weighed and the oven dry weight recorded. The wood blocks treated with NECTEC P paste were coated with the material, oven dried overnight and weighed. Blocks were submerged in three concentrations of each of the four fungicides, at 10, 50, or 100 µg/ml. The submerged blocks underwent vacuum treatment for approximately 10 min at 100 mm Hg to infiltrate the blocks with the fungicide. Blocks were then air dried in room conditions and weighed. The blocks were steam sterilized at 103 kPa 120°C for 20 min, and aseptically transferred to chambers containing actively growing cultures of either M-2 or Y-1 isolates of *C. eremophila*. The chambers were incubated at 30°C for 15 weeks, then disassembled, and the wood blocks brushed free of mycelium, oven dried over 2 days at 93°C, and weighed. Percent weight loss was calculated accounting for additional weight of fungicides according to ASTM procedures.

Since no significant effect but that of the NECTEC P paste was achieved with initial fungicide concentrations (see Results), a second series of trials was run with higher concentrations of the fungicides. Fosetyl-Al and CGA-173506 were dropped from the study but higher concentrations of propiconazole and imazalil were tried. NECTEC blank paste is the paste with no active fungicide ingredients. Each concentration of propiconazole (10,000 µg/ml) and imazalil (20,000 µg/ml) was tested separately to determine which ingredient had the fungicidal or fungistatic effect. Blocks were set up and weight loss determined as in the first trials.

**Fungicide studies: field experiments.** The following materials were used in the first two field studies: fosetyl-Al, CGA-173506 50WP, imazalil, propiconazole, and NECTEC P paste. Branches ranging from 6 to 10 cm in diameter on 25-year-old Lisbon lemon trees and 20-year-old Orlando tangelo trees were used in these trials. Inoculum and autoclaved pieces of wood dowel colonized by *C. eremophila* were prepared as previously described. Prior to inoculation of tree branches, aqueous mixtures containing 100 µg of imazalil or propiconazole per ml were prepared by initially dissolving each fungicide in 95%

**Table 1.** Survey of lemon orchards for wood decay caused by *Coniophora eremophila*, Yuma, Arizona (1993)

| | Percentage of trees in each rating category[z] | | | |
|---|---|---|---|---|
| Grove no. | 0 | I | II | Dead |
| 1 | 46 | 42 | 13 | 0 |
| 2 | 8 | 29 | 38 | 5 |
| 3 | 79 | 4 | 13 | 0 |
| 4 | 79 | 4 | 13 | 0 |
| 5 | 54 | 17 | 33 | 0 |
| 6 | 17 | 83 | 8 | 0 |
| 7 | 0 | 100 | 0 | 0 |
| 8 | 92 | 4 | 4 | 0 |
| 9 | 42 | 25 | 38 | 0 |
| 10 | 79 | 4 | 17 | 0 |
| 11 | 33 | 21 | 38 | 0 |
| Mean | 48 | 30 | 19 | 0.45 |

[z] Twenty-five trees (average age 29 years) were selected from each of 11 orchards, scored for symptoms of decay and the average percent calculated for each category: (0 = no symptoms; I = symptoms; II = questionable for symptoms).

**Table 2.** Development of wood decay caused by *Coniophora eremophila* on various types of citrus trees established on rough lemon rootstock

| | Mean length of decay column (mm)[y] | |
|---|---|---|
| Citrus sp | 1992 | 1993 |
| Valencia orange | 51 ± 12 a[z] | 28 ± 5 a |
| Orlando tangelo | 69 ± 17 a | 35 ± 9 a |
| Marsh grapefruit | 74 ± 25 a | 31 ± 10 a |
| Lisbon lemon | 123 ± 74 b | 104 ± 21 b |

[y] Means were determined from eight inoculated trees.

[z] Means followed by the same letter are not significantly different at $P = 0.05$ according to the Waller-Duncan *k*-ratio *t* test (least significant difference).

**Table 3.** Development of wood decay caused by *Coniophora eremophila* in branches of Lisbon lemon trees established on various rootstocks

| | Mean length of decay column(mm)[y] | |
|---|---|---|
| Rootstock type | 1992 | 1993 |
| Cleopatra mandarin | 187 ± 73 a[z] | 86 ± 19 a |
| Troyer citrange | 152 ± 93 a | 86 ± 18 a |
| Volkameriana | 171 ± 91 a | 86 ± 28 a |
| Rough lemon | 113 ± 97 a | 104 ± 21 a |
| Sour orange | 179 ± 70 a | 106 ± 26 a |
| Macrophylla | 130 ± 100 a | 109 ± 26 a |

[y] Means were determined from eight inoculated trees.

[z] Means followed by the same letter are not significantly different at $P = 0.05$ according to the Waller-Duncan *k*-ratio *t* test (least significant difference).

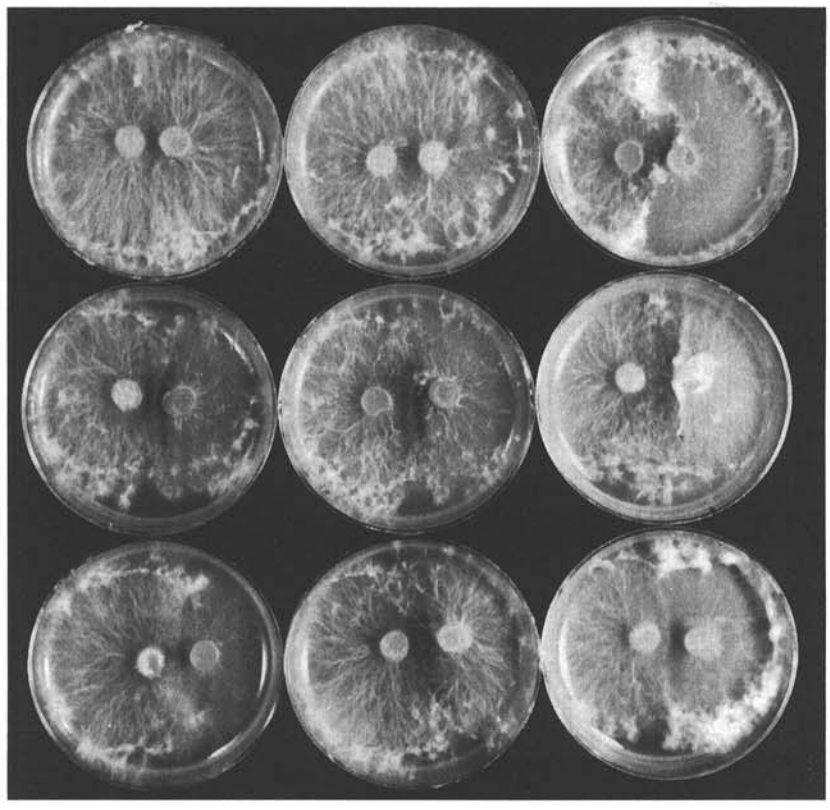

**Fig. 2.** Pairings in culture from nine *Coniophora eremophila* isolates obtained from one mature orchard with brown rot decay symptoms. Top row (left to right): A-1 × A-1, A-1 × A-2, A-1 × G. 2nd row: A-1 × J, A-1 × K-1, A-1 × K-2. 3rd row: A-1 × MD, A-1 × N, A-1 × P.

ethanol, then adding 500 ml of distilled water. Aqueous mixtures of fosetyl-Al or CGA-173506 were prepared by suspending the appropriate amount of each material in 500 ml of water. The NECTEC P paste was used as supplied. Lemon branches were inoculated as previously described. For branches to be treated with a fungicide, the hole in the branch was filled with the test material, then the dowel segment containing the *C. eremophila* was coated with the same fungicide and placed into the hole in the branch. This dowel segment was positioned and retained in the bottom of each inoculation hole by driving another dowel piece, also coated with test fungicide but not containing *C. eremophila,* into each wound and finishing the treatment as previously described. Disease severity was assessed 6 months later by removing infected branches, splitting them in half, and measuring the length of resultant wood decay columns. Inoculated control branches received dowel pieces containing *C. eremophila* but no fungicide was applied to the dowel piece or in the inoculation hole. Noninoculated control branches received dowel pieces that did not contain the pathogen. One branch on each of seven different Lisbon lemon trees and one branch on each of nine different Orlando tangelo trees were used for each treatment.

In a subsequent series of two field trials, the following treatments were used: 10,000 µg of propiconazole per ml, 20,000 µg of imazalil per ml, 10,000 µg of propiconazole + 20,000 µg of imazalil per ml, NECTEC P paste, and the blank paste from which the fungicides were omitted. For each treatment, one branch on each of seven 2-year-old Lisbon lemon or 21-year-old Orlando tangelo trees was inoculated and treated as described earlier. Disease severity was assessed 7 months later. All treatments in the field fungicide trials were arranged in a randomized complete-block design. Values obtained from each trial were analyzed by ANOVA and the Waller-Duncan *k*-ratio *t* test (least significant difference) was used to compare treatment means.

## RESULTS

**Field survey.** In the 11 orchards surveyed a range of decay occurred, from 4 to 100% in mature lemon trees. The average percentage of decayed trees in all orchards was 30% (Table 1).

**Effect of citrus type and rootstock on disease development.** The length of decay columns in inoculated Lisbon lemon branches was significantly greater than that in branches of Orlando tangelo, Marsh grapefruit, or Valencia orange (Table 2). Also, the length of wood decay columns on branches of Orlando tangelo, Marsh grapefruit, and Valencia orange did not differ significantly from each other in both the 1992 and 1993 trials.

There was no significant difference between the length of decay columns that developed on branches of Lisbon lemon trees established on rough lemon, volkameriana, macrophylla, Cleopatra mandarin, sour orange, or Troyer citrange rootstocks (Table 3).

**Pairings in culture.** Pairings of presumptive heterokaryons showed that all pairings between isolates from different trees, including adjacent trees, displayed vegetative incompatibility (evident by dark zones of interaction between isolates). Self-pairings showed no interaction zone (Fig. 2). Pairings between isolates recovered from different areas of the rot column in one branch were compatible, indicating they represented the same genotype (see A-1 × A-2 and K-1 × K-2 in Table 4).

**Fungicide studies: in vitro experiments.** Growth of *C. eremophila* was completely inhibited by CGA-173506 at a concentration of 10 µg/ml and propiconazole at a concentration of 50 µg/ml (Fig. 3). At a concentration of 100 µg/ml, the highest rate tested in this study, imazalil reduced mycelial growth by over 80%. Fosetyl-Al at all tested concentrations had no appreciable effect.

Decayed blocks treated with 10, 50, or 100 µg of fosetyl-Al, CGA-173506, imazalil, or propiconazole per ml showed no significant effect on weight loss compared with inoculated control blocks (Fig. 4). NECTEC P paste was the only treatment that had a significant effect on weight loss. In subsequent trials, NECTEC blank paste without fungicides was the only treatment that inhibited the fungus. The higher concentrations of fungicides compared with earlier studies did not inhibit decay (Table 5).

**Fungicide trials: field experiments.** In the initial field fungicide trials, the length of wood decay columns in branches treated with fosetyl-Al, CGA-173506, imazalil, or propiconazole at a concentration of 100 µg/ml did not differ significantly from that in branches receiving no fungicide treatment (Table 6). On the other hand, the length of decay columns in branches treated with NECTEC P paste was significantly shorter than that recorded in branches receiving no fungicide as well as all other fungicide treatments. In the subsequent field trials, all tested fungicides on Lisbon lemon and Orlando tangelo trees significantly reduced the development of decay columns (Table 7). Equivalent development of decay columns was observed for both Lisbon lemon and Orlando tangelo trees in branches treated with NECTEC P paste (containing 2% imazalil + 1% propiconazole) or the blank paste without fungicides.

**Table 4.** Somatic incompatibility tests for nine isolates of *Coniophora eremophila* collected from one mature orchard[y]

| Isolate of *C. eremophila* | Isolate of *C. eremophila* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A-1 | A-2 | G | J | K-1 | K-2 | MD | N | P |
| A-1 | – | –[z] | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| A-2 | | – | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| G | | | – | ++ | ++ | ++ | ++ | ++ | ++ |
| J | | | | – | ++ | ++ | ++ | ++ | ++ |
| K-1 | | | | | – | –[b] | ++ | ++ | ++ |
| K-2 | | | | | | – | ++ | ++ | ++ |
| MD | | | | | | | – | ++ | ++ |
| N | | | | | | | | – | ++ |
| P | | | | | | | | | – |

[y] –, no interaction zone; ++, strong interaction zone (see text).
[z] A-1 and A-2, K-1 and K-2, were taken from different branches on the same tree in two trees.

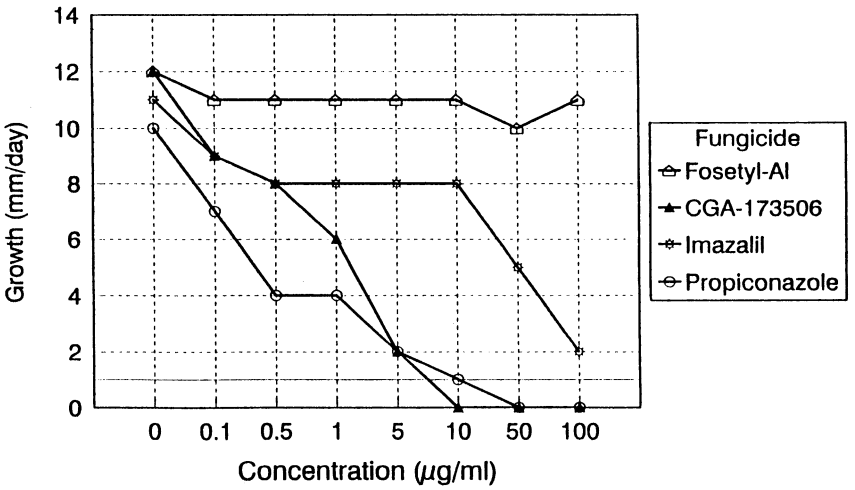


**Fig. 3.** Growth of *Coniophora eremophila* on corn meal agar plates amended with different concentrations of active ingredient after 5 days at 34°C.

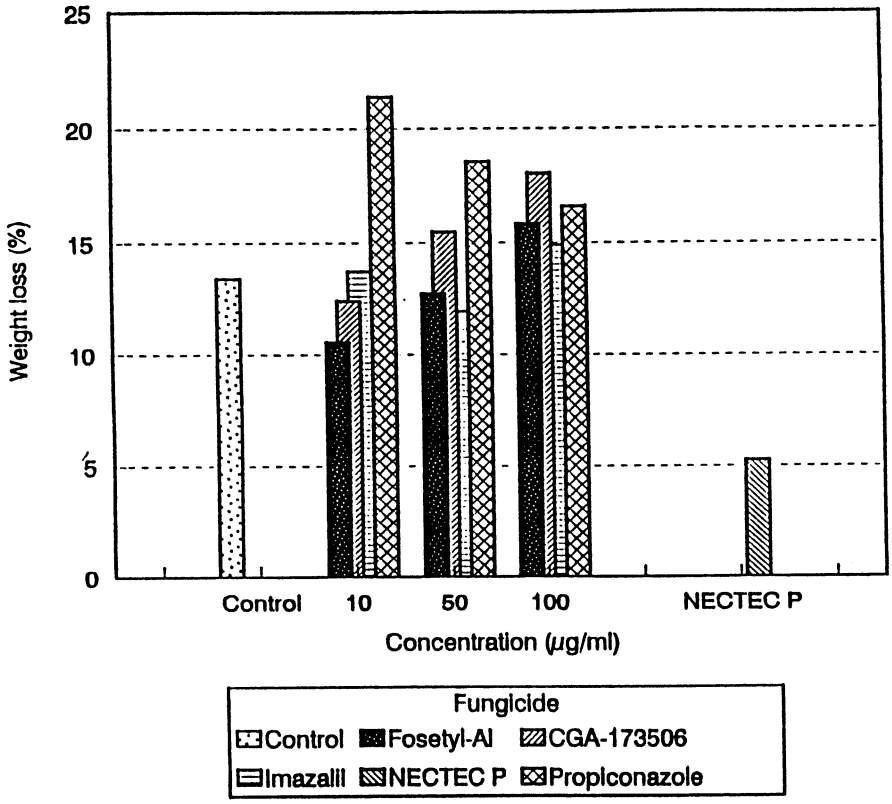


**Fig. 4.** Fungicide tests on Lisbon lemon blocks treated with low concentration of fungicides. The treated and control blocks were inoculated with *Coniophora eremophila*, incubated, and weighed to determine weight loss after 15 weeks in vitro. The mean weight loss of five replicates for each treatment and controls was calculated for each concentration of the fungicides tested.

**Table 5.** Tests on Lisbon lemon blocks treated with concentrations of fungicides imazalil, propiconazole, and NECTEC blank paste inoculated with *Coniophora eremophila* isolate Y-1 or M-2

| Fungicide[x] | Mean percent weight loss[y] |
|---|---|
| Inoculated control | 16.4 ± 3.0 d[z] |
| Control | 8.0 ± 0.6 e |
| Propiconazole Y-1 | 24.6 ± 2.1 a |
| Propiconazole M-2 | 20.1 ± 1.6 bc |
| Imazalil Y-1 | 22.9 ± 3.0 b |
| Imazalil M-2 | 18.6 ± 1.8 cd |
| NECTEC blank Y-1 | 5.3 ± 3.3 ef |
| NECTEC blank M-2 | 3.1 ± 0.7 f |

[x] Concentrations of the fungicides used were 10,000 µg of propiconazole or 20,000 µg of imazalil per ml. NECTEC blank contains no fungicide.

[y] Means were determined from five inoculated blocks.

[z] Means followed by the same letter are not significantly different $P = 0.05$ according to the Waller-Duncan $k$-ratio $t$ test (least significant difference).

## DISCUSSION

*Coniophora eremophila* is the only known *Coniophora* species to grow in the low desert areas of Arizona. It is a major cause of heartwood rot in lemon trees in the Yuma area, causing decay and decline of mature trees. The field survey was carried out to provide an approximate measure of incidence of diseased trees. The overall incidence of 30% diseased trees in the orchards surveyed is high. However, the method used was a conservative one and would tend to underestimate the incidence of the disease. The fungus was isolated from typical brown rot columns in many living trees. Koch's postulates were fulfilled for these isolates on lemon trees. Growth in vitro indicates that this fungus is adapted to high temperatures and can survive up to 40°C (4). Lemon trees are grown in the hotter regions of Arizona, where daily temperatures commonly reach over 40°C in summer.

Our research indicates that different trees are decayed by different genotypes, as evidenced by vegetative incompatibility reactions. These results are similar to those reported (1) for pairings of different wood isolates of *C. puteana*. Sharing of genotypes would indicate probable vegetative spread of the fungus from tree to tree. Presence of different genotypes in adjacent trees or in different wood decay columns in the same tree would indicate probable infection by airborne basidiospores. Decay by *Coniophora* is typically located in trunks and branches and not in roots. Decay apparently originates from airborne basidiospores germinating on pruning wounds or broken or split branches, spreads through the heartwood, and encroaches on the sapwood.

Symptoms of this wood decay include dieback of branches, and breaking of branches and cracking of large tree limbs due to loss of strength properties. Lemon trees bearing heavy fruit commonly show these symptoms, especially when stressed by wind, heavy rain, or other adverse climatic factors. Longitudinal splits often occur on branches with heavy fruit loads and may provide another potential infection court.

Native trees and shrubs occur in close proximity to the Arizona citrus orchards, especially in washes. Basidiocarps of *C. eremophila* on these hosts could provide basidiospores that are aerially dispersed to citrus trees. Basidiospores of this species are thick-walled and presumably could travel large distances without desiccation and loss of viability.

The fungicidal action of the compounds tested was much more pronounced in growth tests on agar media than in growth tests in inoculated trees. This may be due to an even diffusion of the fungicide in the agar medium and a relative immobility in the inoculated branches. Once the fungus grows beyond the impregnated zone it is able to spread more rapidly through the untreated wood. The NECTEC blank paste alone was equally effective as NECTEC P paste with fungicides in inhibiting decay. Apparently, NECTEC blank paste contains some fungistatic compounds. Inoculation tests showed that *C. eremophila* is able to cause wood decay in orange, grapefruit, and tangelo, although significantly less than in lemon. This presumably is due to structural and chemical characters of lemon wood, although we are not aware of data relating to this subject. Decay in lemon trees may be intensified by more intensive pruning and creation of infection courts. Also, lemon may be more subject to cracking and breaking under heavy fruit loads than are other types of citrus. This could also result in a greater incidence of infection courts in lemon with a consequent increase in incidence of decay.

With the limited information currently available on the biology of the fungus and the decay in relation to cultural practices, it is difficult to make specific recommendations for control. Reduction in infection courts would presumably be a primary control measure. Lemon trees grow rapidly and are subjected to heavy pruning annually. Other injuries, such as splitting as a result of heavy fruit load, equipment damage, wind damage, frost cracks, and insect injuries, could also provide suitable infection courts. Treatment of all of these potential infection sites with fungicides is probably unfeasible. Removal of decayed branches as a sanitation practice and treatment of pruning wounds in younger orchards are probably the most effective measures for management of Coniophora decay that can be recommended at the present time.

**Table 6.** Field fungicide trials to control wood decay caused by *Coniophora eremophila* on Lisbon lemon and Orlando tangelo

| Fungicide[x] | Mean length of wood decay column (cm)[y] | |
|---|---|---|
| | Lisbon lemon | Orlando tangelo |
| NECTEC P paste | 1.0 ± 0.0 a[z] | 1.1 ± 0.3 a |
| Imazalil | 29.6 ± 15.3 b | 17.1 ± 4.8 bc |
| Propiconazole | 40.9 ± 29.7 b | 15.7 ± 8.9 b |
| No fungicide | 42.0 ± 18.8 b | 22.8 ± 7.4 c |
| CGA-173506 | 51.3 ± 18.7 b | 19.8 ± 5.4 bc |
| Fosetyl-Al | 83.1 ± 42.1 c | 18.8 ± 9.2 bc |

[x] For all fungicides, a concentration of 100 µg/ml was used; however, NECTEC P paste had 2% imazalil + 1% propiconazole.
[y] Means were determined from eight lemon or nine tangelo tree branches.
[z] Means followed by the same letter are not significantly different at $P = 0.05$ according to the Waller-Duncan *k*-ratio *t* test (least significant difference).

**Table 7.** Field fungicide trials with higher concentrations of fungicides on Lisbon lemon and Orlando tangelo trees inoculated with *Coniophora eremophila*

| Fungicide[x] | Mean length of wood decay column (cm)[y] | |
|---|---|---|
| | Lisbon lemon | Orlando tangelo |
| Uninoculated control | 0.0 ± 0.0 a[z] | 2.9 ± 2.6 a |
| Propiconazole | 0.3 ± 0.7 ab | 0.6 ± 0.9 a[c] |
| Imazalil + propiconazole | 0.4 ± 0.7 ab | 5.1 ± 3.7 b |
| NECTEC blank paste | 1.3 ± 1.7 ab | 2.9 ± 1.0 ab |
| Imazalil | 1.4 ± 0.9 ab | 4.1 ± 3.1 ab |
| NECTEC P paste | 3.6 ± 3.2 b | 4.4 ± 7.7 ab |
| Inoculated control | 7.7 ± 6.4 c | 15.8 ± 6.4 c |

[x] Concentrations of the fungicides used were 10,000 µg of propiconazole or 20,000 µg of imazalil per ml. NECTEC P paste contains 1% propiconazole + 2% imazalil. NECTEC blank paste has no fungicides.
[y] Means were determined from seven inoculated lemon or tangelo tree branches.
[z] Means followed by the same letter are not significantly different at $P = 0.05$ according to the Waller-Duncan *k*-ratio *t* test (least significant difference).


## ACKNOWLEDGMENTS

This research was funded by the Arizona citrus growers through the Arizona Citrus Research Council. We sincerely appreciate their support.


## LITERATURE CITED


1. Ainsworth, A. M., and Rayner, A. D. M. 1990. Mycelial interactions and outcrossing in the *Coniophora puteana* complex. Mycol. Res. 94:627-634.
2. American Society for Testing Materials. 1993. Annual Book of ASTM Standards. American Society of Testing Materials, Philadelphia.
3. Anonymous. 1984. Integrated pest management for citrus. University of California. Statewide IPM Project. Div. Agric. Nat. Res. Pub. 3303.
4. Bigelow, D. M., Gilbertson, R. L., and Matheron, M. E. 1994. Decline and decay of lemon by *Coniophora eremophila* in Arizona (Abstr.). Phytopathology 84:1167.
5. Broadbent, P. 1981. *Armillaria* root rot of citrus in New South Wales, Australia. Proc. Int. Soc. Citric. 1:351-353.
6. Burns, R. M., Klotz, L. J., and Platt, R. G. 1975. Identifying *Ganoderma* fungus. Citrograph 6(3):86 and 90.
7. Farr, D. F. , Bills, G. F., Chamuris, G. P., and Rossman, A. Y. 1989. Fungi on Plants and Plant Products in the United States. American Phytopathological Society, St. Paul, MN.
8. French, A. M. 1987. California plant disease host index. Part I. Fruit and nuts. Calif. Dep. Food Agric., Sacramento.
9. Gilbertson, R. L. 1974. Fungi that Decay Ponderosa Pine. University of Arizona Press, Tucson.
10. Gilbertson, R. L. 1981. North American wood-rotting fungi that cause brown rots. Mycotaxon 12:372-416.
11. Gilbertson, R. L., and Blackwell, M. 1987. Notes on wood-rotting fungi on junipers in the Gulf Coast Region. Mycotaxon 28:369-402.
12. Gilbertson, R. L., Burdsall, H. H., and Canfield, E. R. 1976. Fungi that decay mesquite in southern Arizona. Mycotaxon 3:487-551.
13. Gilbertson, R. L., Goldstein, D., and Lindsey, J. P. 1979. Additions to the check list and host index for Arizona wood-rotting fungi. J. Ariz.-Nev. Acad. Sci. 14:81-87.
14. Gilbertson, R. L., Martin, K. J., and Lindsey, J. P. 1974. Annotated check list and host index for Arizona wood-rotting fungi. Univ. Ariz. Agric. Exp. Stn. Tech. Bull. 209:1-48.
15. Ginns, J. 1982. A monograph of the genus *Coniophora* (Aphyllophorales, Basidiomycetes). Opera Bot. 61:1-61.
16. Ginns, J., and Lefebvre, M. N. L. 1993. Lignicolous Corticioid Fungi (Basidiomycota) of North America. Systematics, Distribution, and Ecology. Mycol. Mem. 19:1-247.
17. Klotz, L. J. 1973. Color Handbook of Citrus Diseases. 4th ed. University of California Div. Agric. Sci., Berkeley.
18. Knorr, L. C. 1973. Citrus Diseases and Disorders. The University Presses of Florida, Gainesville.
19. Lindsey, J. P., and Gilbertson, R. L. 1975. Wood-inhabiting homobasidiomycetes on saguaro in Arizona. Mycotaxon 2:83-103.
20. Matheron, M. E., Gilbertson, R. L., and Matejka, J. C. 1992. *Coniophora* sp. implicated in rapid development of wood rot on living branches of lemon trees in Arizona (Abstr.) Phytopathology 82:1083.
21. Mihail, J. D., and Nelson, M. R. 1989. A relational database for Arizona plant disease records. Plant Dis. 73:702-703.
22. Munnecke, D. E., Kolbezon, M. J., Wilbur, W. D., and Ohr, H. D. 1981. Interactions involved in controlling *Armillaria mellea*. Plant Dis. 65:384-389.
23. Sherman, W. 1994. 1994 Agricultural Statistics. Ariz. Agric. Stat. Serv. Bull. S-29.
24. Sinclair, W. A., Lyon, H. H., and Johnson, W. T. 1987. Diseases of Trees and Shrubs. Comstock Publication Associates, Cornell University Press, Ithaca, NY.
25. Skaria, M. 1990. A pictorial analysis of the growth and development of *Ganoderma* rot on young citrus in Texas. J. Rio Grande Val. Hortic. Soc. 43:85-87.
26. Skaria, M., Smith, G. S., and Gilbertson, R. L. 1990. Root rot of young citrus caused by a species of the *Ganoderma lucidum* complex. (Abstr.) Phytopathology 80:974
27. Stalpers, J. A. 1978. Identification of wood-inhabiting Aphyllophorales in pure culture. Stud. Mycol. 16:1-248.
28. Whiteside, J. O., Garnsey, S. M., and Timmer, L. W. 1988. Compendium of Citrus Diseases. American Phytopathological Society, St. Paul, MN.
29. Whiteside, J. O., and Knorr, L. C. 1970. Mushroom root rot - an easily overlooked cause of citrus tree decline. Citrus Ind. 51:17-20.