Improving Management and Control of Fungal Diseases Affecting Arizona Citrus Trees, 1997[1]

Michael Matheron, Michael Maurer and Martin Porchas

Abstract

Studies were conducted to evaluate potential chemical disease management tools for Alternaria fruit rot on navel oranges and Coniophora brown wood rot on lemon trees, to investigate the possible effect of branch diameter on development of Coniophora wood rot on lemon trees and to summarize our evaluations of citrus rootstocks with respect to relative resistance to root rot and stem canker development when challenged with Phytophthora citrophthora and P. parasitica. We were unable to reduce the level of Alternaria fruit rot on navel oranges with single applications of Abound or copper hydroxide following significant rainfall events. Wood decay in lemon branches inoculated with Coniophora eremophila was significantly suppressed by Abound and a thick formulation of sodium tetrathiocarbonate. The degree of Coniophora brown wood rot in lemon branches of different diameters was variable, although the level of disease in 10 mm diameter branches was significantly smaller than the amount of wood decay in 30 mm diameter branches. Root loss due to Phytophthora citrophthora and P. parasitica in Citrus macrophylla, rough lemon, C. volkameriana and Troyer citrange was lower than most of the 36 different rootstocks tested. On the other hand, root loss on Carrizo citrange, C-35 citrange and sour orange was among the higher values of disease recorded. Stem canker development due to both species of Phytophthora on Troyer citrange, Carrizo citrange, sour orange and Citrus macrophylla was lower than most of the 36 rootstocks tested. Stem cankers on rough lemon and Citrus volkameriana were among the higher values of disease recorded.

Introduction

Pathogenic fungi are responsible for several diseases in Arizona citrus groves. One of these diseases, Alternaria fruit rot caused by the fungus *Alternaria citri*, is commonly found in many navel orange groves in Maricopa County. Annual fruit losses have been estimated to reach 0.5 box per tree. Consistent reduction of Alternaria fruit rot by timely application of fungicides has yet to be achieved. Additional study is needed to develop a reliable disease management approach.

Coniophora brown wood rot has caused extensive destruction in mature lemon plantings in Yuma County. A considerable amount of knowledge has been gained concerning the biology of the pathogen, *Coniophora eremophila*. We know that this fungus grows best at temperatures that occur during the summer in Arizona. All major types of citrus can be attacked by this pathogen; however, disease development is most severe on lemon. There does not appear to be a significant effect of rootstock on disease development in lemon trees. Natural infection is associated with wounds on lemon trees, including stress fractures where branches are cracked but not completely severed from the tree. With respect to potential chemical

[1] The authors wish to thank the Arizona Citrus Research Council for supporting this project. This is the final report for project 97-02 — Improving management and control of fungal diseases affecting Arizona citrus trees, 1997.

tools for disease management, a product called Nectec P and its component active ingredients, propiconazole and imazalil, significantly reduce the amount of wood decay in treated branches.

Many important questions remain to be answered concerning Coniophora brown wood rot. Observational evidence suggests that young lemon wood might be less susceptible than older wood. Also, additional chemical disease management tools may be available. Further research is needed to address these additional questions.

Many disease management tools are available to combat diseases caused by *Phytophthora*. These include cultural methods such as avoiding over-irrigation, chemical methods involving the application of fungicides such as Ridomil or Aliette, and the use of genetic disease resistance when available. The relative resistance or tolerance of commonly used citrus rootstocks has been documented in earlier research studies. Unfortunately, these studies usually relate to tolerance or resistance to only one of the two species of *Phytophthora* that infect citrus in Arizona or only to root rot or only to gummosis. We have developed methods to test 4 to 12 month old citrus rootstock plants under standardized environmental conditions to determine their relative resistance to root rot or gummosis caused by *Phytophthora citrophthora* or *P. parasitica*. These testing methods can be used to compare disease resistance or tolerance of rootstocks currently used as well as potential new citrus rootstocks.

The specific research objectives of these investigations were (1) to continue to test possible chemical disease management approaches for Alternaria fruit rot, (2) to study the effect of wood age as well as fungicides on the rate of Coniophora brown wood rot development, and (3) to continue to test potential new citrus rootstocks for resistance or tolerance to Phytophthora root rot and gummosis.

Materials and Methods

Alternaria fruit rot. A field trial was established in a navel orange grove with a history of Alternaria fruit rot. In a randomized complete block experimental design, treatments consisted of application of Abound (at a rate of 0.2 lb. active ingredient per acre) or Procop (copper hydroxide at a rate of 7.7 lb. active ingredient per acre). Ten replicate trees were treated once with one of these compounds either on 2 July, 5 August or 25 August with two gallons of spray mixture being applied to each tree. The applications on 5 and 25 August were made after significant rainfall events. Ten nontreated trees served as controls. The number of fruit dropping from test trees in this study was recorded from 10 September to 10 November, 1997.

Coniophora brown wood rot. To study the effect of wood age on disease development, branches of various ages (10 , 20, 30, 40, 50, 60, and 70 mm in diameter) on mature lemon trees were inoculated with the fungus by inserting small segments of wood dowels colonized by the pathogen into holes drilled into branches. After 6 months, the inoculated sections of branches were removed from test trees, split open and the length of resulting decay column was recorded. In another experiment, segments of wood dowels colonized by *Coniophora* were treated with various fungicides or wound dressings before inserting into citrus branches. After 6 months, branches were examined and the length of resulting decay column was used to rate the relative ability of each tested material to suppress development of Coniophora brown wood rot relative to the absence of any treatment at all.

Phytophthora root rot and gummosis. In earlier preliminary screening trials, five replicate seedlings of each test rootstock were challenged with either *Phytophthora citrophthora* or *P. parasitica* in the root rot and gummosis studies. Additional trials were conducted on available rootstock material for more extensive evaluation of relative resistance to root rot and gummosis. For the root rot studies, roots of citrus plants were immersed in water containing zoospores of *P. citrophthora* or *P. parasitica* for 48 hr. at 24°C, then planted individually in 4-inch-diameter pots and grown in the greenhouse for approximately 4 months. At the end of each trial, the root weight of inoculated plants compared to noninoculated plants was calculated for each rootstock to determine the percent root loss due to each species of *Phytophthora*. To evaluate rootstocks for relative resistance to stem lesion development (gummosis), plants were stem-inoculated with each pathogen, incubated at 21°C for 12 days in a growth chamber, then the length of stem cankers was measured. Data summarized in this report include experiments conducted from 1993 to 1996, in which rootstocks ranged from 5 to 11 months old for the root rot tests and 4 to 27 months old for stem inoculation trials.

Results and Discussion

Alternaria fruit rot. There was no significant difference in the amount of navel orange fruit drop recorded on trees treated with Abound or Procop in 1997 compared to nontreated trees (Table 1). Apparently, a single application of either compound after a significant rainfall had no effect on the resultant level of disease. Considering these results as well as those presented in earlier reports, we have not been able to develop a reliable disease management approach for Alternaria fruit rot. Further studies concentrating on the biology of disease development could give us the information needed to formulate a working disease management plan.

Coniophora brown wood rot. The amount of wood decay recorded on 10-mm-diameter lemon wood branches in 1997 was significantly smaller than that on 30-mm-diameter branches; results similar to those observed in the 1996 trial (Table 2). On the other hand, the degree of wood decay on branches 10 mm in diameter was not significantly different than decay that occurred on branches 20, 40, 50, 60 and 70 mm in diameter. At this point, the combined data for 1996 and 1997 suggest that development of decay on 10-mm diameter branches is numerically smaller than values on all other size branches tested. This experiment will be conducted again in 1998 to gain additional data.

Different fungicides and wound dressings were tested in 1997 for their potential to suppress development of Coniophora brown wood rot. As illustrated in Table 3, Abound and ETK-1104 were the only tested products that significantly reduced brown wood rot compared to nontreated trees. Considering 1996 and 1997 data, we have identified some potential chemical disease management products, including Nectec P (a combination of propiconazole and imazalil), ETK-1104 (sodium tetrathiocarbonate), and Abound (azoxystrobin). Further evaluation of these materials is planned.

Phytophthora root rot and gummosis. Root rot experiments rate the ability of citrus rootstocks to resist infection by zoospores of *Phytophthora citrophthora* or *P. parasitica*. A summary of root rot evaluation studies, primarily conducted in 1994 and 1995, is presented in Table 4. Each value presented in Table 4 was derived from 10 or 20 individual rootstock plants within 2 or 4 separate experiments, respectively. Among tested rootstocks, *Citrus macrophylla* appeared to be the most tolerant or resistant to root loss due to *P. citrophthora* and *P. parasitica*, demonstrating an average root loss of 33 percent in the presence of both pathogens. Root loss on rough lemon, *C. volkameriana* and Troyer citrange caused by both pathogens was lower than most tested rootstocks and ranged from 34 to 71 percent. In comparison, root loss on Carrizo citrange, C-35 citrange and sour orange ranged from 76 to 90 percent and was among the higher values of disease recorded in these studies. Some of the potential new rootstocks scored well in these trials; however, none were generally superior to rootstocks now in use such as *C. macrophylla*, *C. volkameriana*, rough lemon and Troyer citrange.

The gummosis or stem canker development trials test the relative resistance of stem tissue to growth of both fungal pathogens within bark tissue. A summary of gummosis evaluation studies, primarily conducted in 1993, 1994 and 1996, is presented in Table 5. Each value presented in Table 5 was derived from 10, 20 or 30 individual rootstock plants within 2, 4 or 6 separate experiments, respectively. Troyer citrange, Carrizo citrange, sour orange, *Citrus macrophylla* and C-35 citrange were among the best performers with respect to suppression of stem canker growth when inoculated with *P. citrophthora* and *P. parasitica*, with stem cankers ranging from 2 to 8 mm in length. Rough lemon and *C. volkameriana* were more susceptible to gummosis, with stem cankers ranging from 8 to 16 mm in length after inoculation with the two species of *Phytophthora*. A few of the potential new rootstocks inhibited stem canker formation to a greater degree than any of the tested rootstocks currently in use.

Our results demonstrate that classifying citrus rootstocks as susceptible or resistant to *Phytophthora* cannot be accomplished without defining which Phytophthora disease (root rot or gummosis) and which pathogen (*P. citrophthora* or *P. parasitica*) we are referring to. Also, remember that the results presented here were derived from plants ranging in age from 4 to 27 months old. Tree age, scion, nutrition and other factors that affect the overall health of the tree could affect rootstock resistance or susceptibility to Phytophthora. In spite of the shortcomings of using juvenile plants to predict disease resistance of trees that may have an economic life of at least 30 years or more, these tests allow us to compare relative resistance to Phytophthora diseases in a fairly rapid manner.

Table 1. Maricopa County 1997 Alternaria fruit rot fungicide trial.

Treatment	Rate (a.i. per acre)	Treatment date *			Fruit loss **
		2 Jul	5 Aug	25 Aug	
Abound 2.08F	0.2 lb.	X	--	--	15.4
Procop 77WP	7.7 lb.	X	--	--	17.2
Abound 2.08F	0.2 lb.	--	X	--	17.5
Procop 77WP	7.7 lb.	--	X	--	17.6
Abound 2.08F	0.2 lb.	--	--	X	17.3
Procop 77WP	7.7 lb.	--	--	X	20.7
Nontreated control	-----	--	--	--	18.7

* August applications of fungicides were made after significant rainfall events.

** Average number of navel orange fruit that dropped per tree from 10 September to 10 November, 1997. There were no significant differences between these values.

Table 2. Development of Coniophora brown wood rot on Lisbon lemon tree branches of different diameters.

Branch diameter (mm)	Length of decay column (mm) *		
	1996	1997	Mean
10	4 a	27 a	16
20	15 ab	32 ab	24
30	25 b	48 b	36
40	21 ab	29 ab	25
50	28 b	19 a	24
60	22 b	29 ab	26
70	26 b	23 a	24

* Each value for 1996 and 1997 was determined from 8 and 10 inoculated trees, respectively. Numbers followed by the same letter are not significantly different at P=0.05 using the Duncan-Waller-K-Ratio (LSD) test.

Table 3. Effect of fungicides on development of Coniophora wood rot on Lisbon lemon.

Treatment	Length of wood decay column in mm *	
	1996	1997
Noninoculated control	9 a	9 a
Abound (4% a.i.)	-----	5 a
Nectec P	6 a	-----
Scomrid	45 b	64 bc
ETK-1104	58 bc	15 a
Procop (copper hydroxide, 9% a.i.)	61 bc	74 c
Tree Seal	62 c	59 bc
White tree paint	64 c	-----
Inoculated control	97 c	55 b

* Each value for 1996 and 1997 was determined from 8 and 10 inoculated trees, respectively. Numbers followed by the same letter are not significantly different at P=0.05 using the Duncan-Waller-K-Ratio (LSD) test.

Table 4. Percent loss of root fresh weight of citrus rootstocks inoculated with zoospores of *P. parasitica* or *P. citrophthora*.

Rootstock	Percent root weight loss caused by	
	P. parasitica	*P. citrophthora*
Citrus macrophylla	38 *	27 *
African shaddock x Rubidoux trifoliate	59 *	86 *
Sacaton citrumelo (56-70-2)	60 **	81 **
Sunki mandarin x Flying Dragon trifoliate (62-109-19)	64 **	62 **
Rough lemon	68 **	34 **
Troyer citrange	68 *	66 *
Citrus volkameriana	71 **	52 **
Shekwasha mandarin x English trifoliate (62-137-2)	71 *	60 *
Pineapple sweet orange	72 *	86 *
Milam rough lemon	73 *	92 *
Rich 16-6 trifoliate	75 *	81 *
Soh Jalia rough lemon (58-329-502)	76 *	70 *
Kao Pan shaddock x Swingle trifoliate (55-21-2)	77 *	56 *
C-35 citrange	78 **	85 **
Oklawaha sour orange	78 *	80 *
Zhu Luan sour orange	78 *	89 *
Citrus taiwanica	79 *	68 *
Benton citrange	80 *	84 *
Carrizo citrange	80 **	90 **
Rangpur lime x Kao Phung shaddock (59-121-15)	80 **	84 **
Sunki mandarin x Flying Dragon trifoliate (RN-94-20)	80 *	66 *
Citrumelo 4475	82 *	91 *
Citrumelo 80-8	82 *	84 *
Sour orange	82 *	76 *
CRC 343 grapefruit	84 *	96 *
Smooth Flat Seville sour orange	84 *	92 *
Rangpur lime x Marks trifoliate (RN-94-22)	86 *	87 *
Cleopatra mandarin	87 *	88 *
Savage sour orange x Cleopatra mandarin #2 (63-191-69)	88 *	86 *
Citremon 1449	89 *	78 *
Goutou #1 sour orange	89 *	67 *
Sun Chu Sha mandarin	89 *	96 *
Rangpur lime x Shekwasha mandarin (61-169-2)	90 **	65 **
Savage sour orange x Cleopatra mandarin #1 (63-191-22)	92 **	84 **
Sicilian sour orange x Cleopatra mandarin #2 (F-163-192-51)	92 *	95 *
Gomiri rough lemon (62-437-501)	93 *	74 *
LSD (P=0.05) ***	19	19

* Each value represents the average root loss sustained by 10 rootstock plants from two separate experiments conducted during 1994 or 1995.

** Each value represents the average root loss sustained by 20 rootstock plants from four separate experiments conducted during 1994 and 1995.

*** Root weight differences equal to or greater than the LSD (Least Significant Difference) value are significantly different (P=0.05).

Table 5. Development of stem cankers on citrus rootstock plants infested with *P. parasitica* or *P. citrophthora*.

Rootstock	Length of stem canker in mm caused by *P. parasitica*	Length of stem canker in mm caused by *P. citrophthora*
Rangpur lime x Marks trifoliate (RN-94-22)	0 **	3 **
Rangpur lime x Marks trifoliate (RN-94-20)	1 **	2 **
Citrus obovoidea	3 **	3 **
Troyer citrange	3 **	8 **
Carrizo citrange	4 **	5 **
Citremon 1449	4 **	7 **
Shekwasha mandarin x English trifoliate (62-137-2)	4 **	2 **
Sour orange	4 **	8 **
Sunki mandarin x Flying Dragon trifoliate (62-109-19)	4 **	2 **
Sunki mandarin x Flying Dragon trifoliate (RN-94-20)	4 **	2 **
African shaddock x Rubidoux trifoliate	5 **	4 **
Citrumelo 4475	5 *	5 *
Savage sour orange x Cleopatra mandarin #2 (63-191-69)	5 *	4 *
Citrus macrophylla	6 *	8 *
Zhu Luan sour orange	6 **	6 **
C-35 citrange	7 **	2 **
Citrumelo 80-8	7 *	2 *
Pineapple sweet orange	7 *	24 *
Rangpur lime x Shekwasha mandarin (61-169-2)	7 **	5 **
Citrus volkameriana	8 ***	9 ***
Sacaton citrumelo	8 **	12 **
Smooth Flat Seville sour orange	8 **	6 **
Oklawaha sour orange	8 **	4 **
Sicilian sour orange x Cleopatra mandarin #2 (F-163-192-51)	9 **	10 **
Soh Jalia rough lemon (58-329-502)	10 **	3 **
Sun Chu Sha mandarin	11 *	6 *
CRC 343 grapefruit	12 *	14 *
Goutou #1 sour orange	12 *	2 *
Rangpur lime x Kao Phung shaddock (59-121-15)	12 **	16 **
Rough lemon	12 ***	16 ***
Benton citrange	13 *	5 *
Cleopatra mandarin	13 **	10 **
Savage sour orange x Cleopatra mandarin #1 (63-191-22)	13 *	4 *
Rich 16-6 trifoliate	14 *	4 *
Citrus taiwanica	15 *	9 *
Gomiri rough lemon (62-437-501)	16 **	9 **
LSD (P=0.05) [2]	5	5

1 Two experiments were conducted during 1993, 1994 or 1996. Each value represents the average length of stem canker from 10 (*), 20 (**) or 30 (***) rootstock plants from 2, 4 or 6 separate experiments, respectively.

2 Stem canker length differences equal to or greater than the LSD (Least Significant Difference) value are significantly different (P=0.05).