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

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Abstract

Experiments were initiated to evaluate chemical disease management tools for Alternaria fruit rot on navel orange and Coniophora brown wood rot on lemon trees, examine the possible effect of branch diameter on development of Coniophora wood rot on lemon trees and continue evaluations of relative resistance of rootstocks to root rot and stem canker development when inoculated with P. citrophthora and P. parasitica. Rovral or Kocide did not significantly reduce the amount of Alternaria fruit rot on navel orange trees occurring in late summer and early autumn when applied during the preceding winter or spring months. Of several chemical treatments tested, only Nectec paste inhibited the development of Coniophora brown wood rot on inoculated lemon branches. The size of wood decay columns on branches 10 mm (0.5 inch) in diameter were significantly smaller than those developing on branches 50-70 mm (2.0-2.75 inches) in diameter. In extensive trials evaluating root rot caused by Phytophthora citrophthora and P. parasitica, some relatively tolerant rootstocks were found among the group of new potential rootstocks as well as currently used rootstocks such as rough lemon, C. macrophylla and Troyer citrange. C. volkameriana was relatively tolerant to the development of root rot by P. citrophthora but demonstrated variable tolerance to P. parasitica. Comprehensive evaluation of stem canker development on citrus rootstocks inoculated with P. citrophthora or P. parasitica revealed that rough lemon is usually highly susceptible to both pathogens, while C. volkameriana was at times less susceptible (more tolerant) than rough lemon to both pathogens. Some of the new potential rootstocks were highly tolerant or resistant to infection of stem tissue by P. citrophthora or P. parasitica.

Introduction

Several diseases caused by pathogenic fungi affect citrus groves in Arizona. One of these diseases, Alternaria fruit rot, is routinely found in most navel orange groves in Maricopa County and can cause annual fruit losses of up to 0.5 box per tree. Another disease, Coniophora brown wood rot, has caused extensive destruction in mature lemon plantings in Yuma County. Finally, Phytophthora root rot and gummosis affects a majority of citrus plantings in Yuma and Maricopa Counties.

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A field study conducted in 1995 identified a treatment and application schedule that significantly reduced the severity of navel orange fruit drop induced by the pathogenic fungus *Alternaria citri*. A single treatment of trees with a copper fungicide in December, January, or February resulted in lower levels of fruit drop compared to a similar treatment in November or March or to no treatment at all. Applications of another fungicide (Rovral) from March through August did not reduce the severity of fruit drop compared to nontreated trees. Additional field trials are needed to validate the findings of this 1995 test.

Much has been learned about the biology of the wood rot fungus *Coniophora* and the development of brown wood rot in citrus. The fungus grows best at temperatures that occur in the summer in Arizona. The fungus can attack all major types of citrus, but disease development is most severe on lemon. There appears to be no significant effect of rootstock on disease development in lemon trees. Infection is associated with wounds on lemon trees, including stress fractures where branches are cracked but not completely severed from the tree. Finally, growth of the fungus within citrus wood tissue is reduced significantly in the presence of a fungicidal preparation called Nectec paste. However, important questions remain concerning this disease. Observational evidence suggests that young lemon wood might be less susceptible than older wood. Also, additional types of treatments other than application of Nectec paste may be useful for prevention of infection. Further research is needed to address these additional questions.

When available, the use of tolerant or resistant plant material is always desirable as a disease management tool. Earlier researchers have documented the relative resistance of the commonly used citrus rootstocks to Phytophthora. Unfortunately, these studies may relate to tolerance or resistance to only one of the two species of *Phytophthora* or only to root rot or only to gummosis. We have developed methods to assay citrus rootstock seedlings under standardized environmental conditions to determine their relative resistance to root rot or gummosis caused by *Phytophthora citrophthora* or *P. parasitica*. To date, these methods have been used to evaluate 36 different rootstocks in preliminary trials. The promising rootstocks in these preliminary screening trials should be subjected to more extensive tests. Additional new rootstocks are available that should be tested as well.

The specific research objectives addressed during these studies were as follows: (1) **Alternaria fruit rot** - Conduct additional field study to confirm results of fungicide trials conducted earlier; (2) **Coniophora brown wood rot** - Study the effect of branch diameter (branch age) on development of wood decay on lemon trees and evaluate wound dressings as preventative treatments for disease management; (3) **Phytophthora root rot and gummosis** - Test promising resistant rootstocks from preliminary screening experiments in more extensive trials. The fulfillment of these objectives should enhance our efforts to improve the management of these diseases of citrus.

Materials and Methods

Alternaria fruit rot. A two-part field trial was established in a navel orange grove with a history of Alternaria fruit rot. In one part of this study, a group of trees was treated once with a copper fungicide (Kocide 20/20; 7.5 lb. product/A; 50 gal/A at 40 psi applied with a commercial airblast sprayer) during December, January, February, March, April or May. In the other part of the study, six groups of five 2-tree replicates were established. One group served as the nontreated control, while one of the five remaining groups were treated with the fungicide Rovral (1.0 lb. a.i./A; 480 gal/A at 100 psi with hand-gun application to thoroughly wet leaves and fruit with spray solution) in November, December, January, February or March. The number of fruit dropping from experimental trees were recorded weekly from August 5 until October 24.

Coniophora brown wood rot. To examine 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 the branches. After 9 months, the inoculated sections of branches were removed from the test trees, split open and the length of the resulting decay column was recorded. In another trial, segments of wood dowels colonized by *Coniophora* were treated with Nectec paste or various types of wound dressings before inserting into citrus branches. After 9 months, branches were examined and the length of resulting decay columns were recorded to assess the relative ability of each tested material to suppress development of Coniophora brown wood rot relative to inoculated branches not treated with any chemical.

Phytophthora root rot and gummosis. Preliminary greenhouse screening trials involved subjecting five replicate seedlings of each test rootstock to each species of *Phytophthora* for the root rot test or for the gummosis test. Additional trials were conducted on available rootstock material for more extensive evaluation of relative resistance to root rot and gummosis. For root rot studies, the roots of 5-11-month-old 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 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), 4-27-mo-old 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 for relative root loss from 1994 and 1995 as well as relative development of stem lesions from 1993, 1994 and 1996 studies are presented.

Results and Discussion

Alternaria fruit rot. As can be observed from the data presented in Table 1, there was no significant difference in the amount of navel orange fruit drop recorded on nontreated trees when compared to a single treatment with Rovral fungicide in November, December, January, February or March as well as Kocide applied once in December, January, February, March, April or May. These findings do not validate data from the 1995 trial, in which an application of Kocide during the winter months resulted in lower levels of disease. Considering the combined results from 1995 and this year, we must conclude that Kocide or Rovral applied according to the protocol outlined earlier is not an effective management tool for Alternaria navel orange fruit rot. Continued exploration for other fungicides and/or different timing of application is needed to develop management strategies for this disease.

Coniophora brown wood rot. The size of the wood decay column on 10-mm-diameter lemon wood branches was significantly smaller than those developing on branches 50 to 70 mm in diameter on the same tree (Table 2). Remember, this experiment must be repeated to confirm these results; however, this data supports other observational evidence indicating that younger (and smaller diameter) branches are less susceptible to *Coniophora* compared to older and larger branches. If further trials confirm these findings, growers will not have to be concerned about hedging wounds on small branches as hospitable avenues of infection for the brown wood rot fungus.

Several different wound treatments were tested for their potential as inhibitors of brown wood rot development. As shown in Table 3, Tree Seal, white tree trunk paint, Gowan Procop (copper hydroxide) as well as an experimental fungicide (ETK-1104) did not impede the growth of *Coniophora* compared to nontreated branches. As in earlier studies, Nectec paste significantly blocked the growth of *Coniophora*. Scomrid Limb, an aerosol formulation containing the same active ingredients as Nectec paste, was significantly less effective than Nectec paste in restricting growth of the fungal pathogen in lemon wood. Nectec paste is a proven deterrent to Coniophora brown wood rot in lemon wood; however, it is still not registered for use on any food crop in the United States. The search for a useable agrochemical disease management tool for this disease will continue.

Phytophthora root rot and gummosis. The root rot tests evaluate the ability of citrus rootstocks to resist infection by zoospores of *Phytophthora citrophthora* or *P. parasitica*. During trials conducted in 1994 and 1995, 36 different rootstocks were compared with respect to the amount of root weight loss due to infection with *Phytophthora citrophthora* and *P. parasitica*. The results of these studies are found in Tables 4-5. Each numerical entry was derived from five separate rootstock plants in each of two separate trials for a total of 10 rootstock plants for each year. Among the best performers with respect to root loss due to *P. citrophthora* are several rootstocks currently in use, such as *Citrus macrophylla*, rough lemon, Troyer citrange and *C. volkameriana*. Some potential new rootstocks were relatively tolerant to *P. citrophthora* as well. With respect to tolerance to *P. parasitica*, the currently used rootstocks *C. macrophylla*, rough lemon and Troyer citrange proved to be relatively tolerant. *C. volkameriana*, as well as some other rootstocks tested in 1994 and 1995, demonstrated variable tolerance to root rot caused by *P. parasitica*.

The gummosis or stem canker development trials test the relative resistance of stem tissue to growth of both fungal pathogens

within bark tissue. Data presented in Tables 6-8 are from studies conducted in 1993, 1994 and 1996. Among the commonly used rootstocks tested in 1993 (Table 6), development of stem cankers on sour orange, *Citrus macrophylla*, and Troyer citrange was significantly less than that recorded on rough lemon, when inoculated with either *P. citrophthora* or *P. parasitica*. Except for the 1994 trial on seedlings inoculated with *P. citrophthora*, all tests conducted in 1993, 1994 and 1996 reveal that rough lemon is highly susceptible to the development of cankers by both species of *Phytophthora*. In these same trials, stem canker growth on *C. volkameriana* was sometimes equal to and sometimes less than that recorded on rough lemon. C-35 citrange and some potential new rootstocks performed well in the stem canker trials of 1994 and 1996 (Tables 7-8). As shown by the Soh Jalia rootstock, tolerance to gummosis initiated by *P. citrophthora* occasionally does not carry over to tolerance for *P. parasitica*.

Variability between experiments is a common occurrence in biological research of this nature. Although a conclusive reason for the variability observed can not be presented, it is important to remember that several factors influence the development of a plant disease. The pathogen, the host and the environment in which the pathogen and host interact affect the resultant severity of any plant disease. We strive to minimize these differences during the execution of an experiment, but the only way to develop confidence in the outcome of such trials is to perform them several times, so that the effects of the uncontrollable variables will be diminished. The root rot trial data presented in Tables 4 and 5 each represent two separate experiments for a total of 4 different root rot studies. The stem canker ratings presented in Tables 6, 7 and 8 were derived from 3, 2 and 2 separate experiments, respectively, for a total of 7 different stem canker studies.

The relative ratings of rootstocks with respect to susceptibility or tolerance to root rot or stem canker development in the presence of *P. citrophthora* or *P. parasitica* provide useful information regarding disease risk for rootstocks currently in use as well as for potential new rootstocks of the future.

Table 1. Maricopa County 1996 Alternaria fruit rot fungicide trial

Treatment month	Fruit drop [1]
Treated with Rovral	
Nontreated control	56 a
November, 1995	61 a
December, 1995	56 a
January, 1996	56 a
February, 1996	70 a
March, 1996	60 a
Treated with Kocide	
December, 1995	72 a
January, 1996	55 a
February, 1996	56 a
March, 1996	70 a
April, 1996	75 a
May, 1996	75 a

1 Average number of navel orange fruit that dropped per tree from August 5 to October 24, 1996. There were no significant differences between these values.

Table 2. Relative development of Coniophora brown wood rot on lemon tree branches of various diameters.

Branch diameter in mm	Length of wood decay column in mm [1]
10	4 a
20	15 ab
30	25 b
40	21 ab
50	28 b
60	22 b
70	26 b

1 Each value was determined from eight inoculated trees. Numbers followed by the same letter are not significantly different at P=0.05 using the Duncan-Waller K-Ratio (LSD) test.

Table 3. Development of Coniophora brown wood rot on lemon tree branches treated with various materials.

Treatment	Length of wood decay column in mm [1]
Nectec Paste	6 a
Noninoculated control	9 a
Scomrid Limb	45 b
ETK-1104	58 bc
Gowan Procop (copper hydroxide)	61 bc
Tree Seal	62 c
White tree trunk paint	64 c
Inoculated control	97 c

1 Each value was determined from eight inoculated trees. Numbers followed by the same letter are not significantly different at P=0.05 using the Duncan-Waller K-Ratio (LSD) test.

Table 4. Root loss sustained by citrus rootstock plants infested with *Phytophthora citrophthora* or *P. parasitica* in 1994 studies.

Rootstock	Percent root weight loss caused by *P. citrophthora*	*P. parasitica*
Citrus macrophylla (YMAC)	27 a [1]	39 a
Rough lemon (YMAC)	31 a	72 cde
Citrus volkameriana (YMAC)	33 a	51 ab
Sunki x Flying Dragon (62-109-19)	43 a	54 abc
Troyer citrange (YMAC)	66 b	68 bcd
Sunki x Flying Dragon (RN-94-20)	66 b	80 def
Citrus taiwanica	68 bc	79 def
Rangpur lime x Shakwasha (61-169-2)	68 bc	88 ef
Sacaton citrumelo (56-70-2)	75 bcd	47 a
Sour orange (YMAC)	76 bcd	82 def
Savage sour x Cleopatra mandarin #1 (63-191-22)	77 bcd	88 ef
Citremon 1449	78 bcd	89 ef
C-35 citrange	79 bcd	73 de
Rangpur lime x Kao Phuang shaddock (59-121-15)	79 bcd	75 def
Oklawaha sour orange	80 bcd	78 def
Rough lemon	85 cd	93 f
Pineapple sweet orange (YMAC)	86 cd	72 cde
Rangpur lime x Marks trifoliate (RN-94-22)	87 d	86 def
Carrizo citrange	89 d	83 def

1 Each value represents the average root loss sustained by 10 individual rootstock plants ranging from 5-11 months old. Values in each column followed by a different letter are significantly different (P=0.05) according to the Duncan-Waller K-Ratio (LSD) test.

Table 5. Root loss sustained by citrus rootstock plants infested with *Phytophthora citrophthora* or *P. parasitica* in 1995 studies.

Rootstock	Percent root weight loss caused by *P. citrophthora*	*P. parasitica*
Rough lemon (YMAC)	37 a[1]	64 ab
Kao Pan shaddock x Swingle citrumelo (55-21-2)	56 b	77 bcdef
Shakwasha x English trifoliate (62-137-2)	60 bc	71 abc
Rangpur lime x Shakwasha (61-169-2)	62 bc	91 fgh
Gou Tou #1 sour orange	67 bcd	89 efgh
Soh Jalia (58-329-502)	70 bcde	76 bcde
Citrus volkameriana (YMAC)	71 bcdef	91 fgh
Gomiri rough lemon (62-437-501)	74 cdefg	93 gh
Citrus volkameriana	79 defgh	94 h
Rich 16-6 trifoliate	81 defghi	75 bcd
Sunki x Flying Dragon (62-109-19)	81 defghi	73 bc
Benton citrange	84 efghij	80 cdefg
Citrumelo 80-8	84 efghij	82 cdefgh
Savage sour x Cleopatra #2 (63-191-69)	86 fghij	88 defgh
African shaddock x Rubidoux trifoliate	86 fghij	59 a
Sacaton citrumelo (56-70-2)	87 ghij	73 bc
Cleopatra mandarin	88 ghij	87 defgh
Rangpur lime x Kao Phuang shaddock (59-121-15)	89 ghij	84 cdefgh
Zhu Luan	89 ghij	78 cdef
C-35 citrange	91 hij	82 cdefgh
Citrumelo 4475	91 hij	82 cdefgh
Carrizo citrange	92 hij	77 bcdef
Savage sour x Cleopatra mandarin #1 (63-191-22)	92 hij	95 h
Smooth Flat Seville sour orange	92 hij	84 cdefgh
Milam rough lemon	92 hij	73 bc
Sicilian sour x Cleopatra mandarin #2 (F-163-192-51)	95 ij	92 gh
CRC 343 grapefruit	96 j	84 cdefgh
Sun Chu Sha mandarin	96 j	89 efgh

1 Each value represents the average root loss sustained by 10 individual rootstock plants ranging from 5-6 months old. Values in each column followed by a different letter are significantly different (P=0.05) according to the Duncan-Waller K-Ratio (LSD) test..

Table 6. Development of stem cankers on young citrus rootstock plants infested with *Phytophthora citrophthora* or *P. parasitica* in 1993 studies.

Rootstock	Length of stem canker in mm	
	P. citrophthora	*P. parasitica*
Sour orange (YMAC)	8.0 a[1]	7.4 b
Citrus macrophylla (YMAC)	8.4 a	6.0 b
Troyer citrange (YMAC)	8.6 a	2.1 a
Citrus volkameriana (YMAC)	11.3 a	10.6 c
Rough lemon (YMAC)	20.2 b	12.0 c
Sweet orange (YMAC)	24.3 b	6.8 b

1 Each value represents the average length of stem canker on 20 individual 4-month-old rootstock plants 12 days after inoculation. Values in each column followed by a different letter are significantly different (P=0.05) according to the Duncan-Waller K-Ratio (LSD) Test.

Table 7. Development of stem cankers on young citrus rootstock plants infested with *Phytophthora citrophthora* or *P. parasitica* in 1994 studies.

Rootstock	Length of stem canker in mm	
	P. citrophthora	*P. parasitica*
C-35 citrange	0.2 a[1]	0.3 a
Sicilian sour orange x Cleopatra mandarin #2 (F-163-192-51)	0.2 a	3.6 abcd
Shakwasha x English trifoliate (62-137-2)	1.1 ab	0.6 a
Rough lemon	1.2 abc	6.4 cde
Sunki x Flying Dragon (62-109-19)	1.4 abc	0.5 a
Soh Jalia (58-329-502)	1.5 abc	6.1 cde
Sunki x Flying Dragon (RN-94-20)	1.9 abc	3.5 abcd
Rough lemon (YMAC)	2.0 abc	9.1 ef
Gomiri rough lemon (62-437-501)	2.2 abc	16.8 gh
Gou Tou	2.3 abc	12.0 fg
Rangpur lime x Marks trifoliate (RN-94-22)	2.6 abc	0.2 a
African shaddock x Rubidoux trifoliate	2.6 abc	4.9 abcde
Rangpur lime x Marks trifoliate (RN-94-23)	2.8 abcd	1.1 ab
Citrus volkameriana (YMAC)	2.8 abcd	6.0 cde
Citrus obovoidea	3.0 abcd	3.3 abc
Savage sour x Cleopatra #1 (63-191-22)	3.5 bcd	13.0 fg
Rangpur lime x Shakwasha (61-169-2)	3.7 bcd	5.7 bcde
Oklawaha sour orange	3.8 bcd	8.3 def
Carrizo citrange	4.0 cd	0.5 a
Smooth Flat Seville sour orange	5.5 de	4.8 abcde
Citremon 1449	6.9 ef	4.4 abcde
Troyer citrange (YMAC)	7.4 ef	3.2 abc
Citrus taiwanica	9.0 f	14.9 gh
Rangpur lime x Kao Phuang shaddock (59-121-15)	12.1 g	18.5 h
Sacaton citrumelo (56-70-2)	18.1 h	8.3def

1 Each value represents the average length of stem canker on 10 individual 12-month-old rootstock plants 12 days after inoculation. Values in each column followed by a different letter are significantly different (P=0.05) according to the Duncan-Waller K-Ratio (LSD) Test.

Table 8. Development of stem cankers on young citrus rootstock plants infested with *Phytophthora citrophthora* or *P. parasitica* in 1996 studies.

Rootstock	Length of stem canker in mm	
	P. citrophthora	*P. parasitica*
Citrumelo 80-8	1.6 a[1]	6.6 ab
Sunki x Flying Dragon (62-109-19)	2.3 a	7.5 abcd
Shakwasha x English trifoliate (62-137-2)	3.2 a	8.0 abcd
Savage sour x Cleopatra #2 (63-191-69)	3.5 a	5.1 a
C-35 citrange	4.0 a	14.5 fg
Rich 16-6 trifoliate	4.4 a	13.6 fg
African shaddock x Rubidoux trifoliate	4.6 a	5.7 a
Soh Jalia (58-329-502)	4.9 a	13.0 efg
Benton citrange	5.3 ab	13.0 efg
Citrumelo 4475	5.3 ab	5.4 a
Zhu Luan	5.5 ab	6.1 a
Sun Chu Sha mandarin	5.6 ab	10.7 bcdef
Smooth Flat Seville sour orange	6.1 abc	11.7 cdefg
Sacaton citrumelo (56-70-2)	6.1 abc	8.0 abcd
Carrizo citrange	6.2 abc	7.6 abcd
Rangpur lime x Shakwasha (61-169-2)	6.2 abc	7.4 abc
Cleopatra mandarin	9.8 bcd	13.1 efg
Citrus volkameriana	10.6 cd	15.2 fg
Citrus volkameriana (YMAC)	13.3 de	8.6 abcde
CRC 343 grapefruit	13.6 de	12.0 defg
Gomiri rough lemon (62-437-501)	16.4 ef	15.9 g
Rangpur lime x Kao Phuang shaddock (59-121-15)	18.9 f	4.9 a
Sicilian sour orange x Cleopatra mandarin #2 (F-163-192-51)	19.1 f	14.2 fg
Rough lemon (YMAC)	25.0 g	15.2 fg

1 Each value represents the average length of stem canker on 10 individual 27-month-old rootstock plants 12 days after inoculation. Values in each column followed by a different letter are significantly different (P=0.05) according to the Duncan-Waller K-Ratio (LSD) Test.