Effect of Fertilizer Nitrogen Source on Susceptibility of Five Species of Field-Grown Palms to *Fusarium oxysporum* f. sp. *canariensis*

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Several Fusarium wilt diseases (FW) attack palms worldwide. The fungus *Fusarium oxysporum* f. sp. *canariensis* causes FW of Canary Island date palm (CIDP, *Phoenix canariensis*). FW is a devastating and fatal disease in California, Florida and many other states and countries where CIDPs are grown. Feather et al. (1979) first described FW of CIDP in California and determined that it was spread in soil and by pruning equipment and was untreatable with fungicides. Because *Fusarium oxysporum* f. sp. *canariensis* is considered a soil-borne pathogen, it is widely recommended not to replant CIDPs in a location where one has died from FW. However, it is thought that other species of palms, even other *Phoenix* species, could be replanted without fear of infection because *F. oxysporum* typically has

strictly host species-specific forms. For example the form of *F. oxysporum* that attacks CIDPs would not attack other species of palms. However, Feather at al. (1989) showed that the form of *F. oxysporum* that attacked CIDPs could also infect and kill seedlings of the date palm of commerce (*P. dactylifera*) although their work was based on artificially inoculated palms grown in containers. Priest and Letham (1996) were unable to corroborate Feather's findings with the date palm of commerce but were able to infect Senegal date palms (*P. reclinata*) with *F. oxysporum* f. sp. *canariensis* and create disease. Also, Howard Ohr (pers. comm.) established that *F. oxysporum* f. sp. *canariensis* could attack and kill California fan palms (*Washingtonia filifera*). Although Ohr's work is unpublished, Summerell et al. (2001) made similar observations in Australia. Thus, the susceptibility of other species of palms to *Fusarium oxysporum* f. sp. *canariensis* needs further study.

Because CIDPs are highly valued as landscape specimens due to their unique and imposing habit, there is a strong desire to maintain their presence in landscapes even after they have succumbed to FW. Indeed, while CIDPs replanted at the same location where one had succumbed previously from FW often die, anecdotal observations show that occasionally they survive. Unfortunately, nothing is known of why some CIDPs survive under these conditions. Keim and Humphrey (1984) showed that nitrate fertilizers increased and

1. *Phoenix reclinata* with Fusarium wilt, 2010, UC SCREC, Irvine, California (D.R. Hodel).

ammoniacal fertilizers prevented FW in the woody shrub veronica (*Hebe* sp.). Both ammonium and nitrate are typically used in palm fertilizers and, thus, perhaps could account for the survival of some CIDPs replanted in soils infested with *Fusarium oxysporum* f. sp. *canariensis*.

An opportune situation was presented to us when in 2004 we planted out 30 CIDPs for a long-term pruning study in a field at the University of California South Coast Research and Extension Center (UC SCREC) in Irvine that 25 years previously had been home to CIDPs inoculated with *Fusarium oxysporum* f. sp. *canariensis* as part of the Feather et al. (1979) FW study. Although the field had been fallow for the intervening 25 years (kept free of all plant growth, including weeds), by 2007 nearly all these palms, which had not yet been pruned, began to show symptoms of FW and over half had died. By 2010 all 30 palms had died from FW. That the pathogen could remain active in a fallow field after 25 years and then infect newly planted CIDPs was remarkable and provided us the opportunity to assess susceptibility of other species of palms and determine if the form of nitrogen in fertilizer could affect susceptibility to FW.

Materials and Methods

In 2008 we initiated this study in the same field inoculated with *Fusarium oxysporum* f. sp. *canariensis* at the UC SCREC in Irvine where the 30 CIDPs had previously died from FW. We planted out 25 palms each of five species grown in 3.8 L (one-gallon) containers: *Phoenix canariensis, P. dactylifera* (seedlings of 'Deglet Noor'), *P. reclinata*, *P. roebelenii* (pygmy date palm) and *Washingtonia filifera*. Each palm was selected for uniformity in size, growth, vigor and health. We established the experiment in blocks with five replications. Each block was subdivided into five sub-blocks, each of which contained one palm each of the five species and was fertilized with one of five fertilizer treatments: untreated, ammonium sulfate, calcium nitrate, calcium-ammonium nitrate and Best Palm Plus [13(4.8 ammoniacal nitrogen, 8.2 urea nitrogen)-5-8-2.8(Mg), complete, controlled-release, palm-special fertilizer, J. R. Simplot, Lathrop, CA]. Fertilizers were applied to the soil surface and lightly incorporated into the soil around the newly planted palms to supply 0.454 kg of actual nitrogen per palm. After one year the same amount of fertilizer was applied again. Irrigations were scheduled to provide 80% of reference evapotranspiration for the site. The experiment was a two-factor, factorial, randomized complete-block design.

We determined palm growth by initially marking the newest leaf and then counting subsequent leaves produced and measuring palm volume every six months: length × width × height. Each symptomatic palm was tested for presence of *Fusarium oxysporum* f. sp. *canariensis*. Petioles of dying or dead trees were washed and soaked in 10% household bleach for five minutes and rinsed in sterile water. Using flame sterilized knives and pruning shears, petioles were opened and tissue pieces were placed on acidified ¼ strength Difco (Becton, Dickinson and Co, Sparks, MD) potato dextrose agar (10 g PDA and 10 g agar with 1 ml lactic acid/L deionized water). Cultures were incubated at 24C and allowed to grow for up

Table 1. Susceptibility of field-grown *Washingtonia filifera* and four species of *Phoenix* to *Fusarium oxysporum* f. sp. *canariensis*, 2009-2012, UC SCREC, Irvine, California.

	P. canariensis	*P. reclinata*	*P. roebelenii*	*P. dactylifera*	*Washingtonia filifera*
Number Dead Palms[z]	25	12	0	0	14
Percent Probability of Death[y]	100	44.6	0	0	56.0
P value	0.009	0.009	0.009	0.009	0.009

[z] Number of palms out of 25 for each species that died and tested positive for *Fusarium oxysporum* f. sp. *canariensis*.

[y] Percent probabilities of death due to *Fusarium oxysporum* f. sp. *canariensis* were made with a binary logistic regression model that had significant Chi Square values (χ^2=98.786; six degrees of freedom).

to ten days or until colonies containing macroconidia typical of *Fusarium oxysporum* were identified. *Fusarium oxysporum* f. sp. *canariensis* were verified using PCR methods and primers (Plyler et al. 1999). Total number of dead palms due to *Fusarium oxysporum* f. sp. *canariensis* was recorded at the end of the trial. Data were subjected to two-way analysis of variance (ANOVA), and probabilities of death due to *Fusarium oxysporum* f. sp. *canariensis* were made with a binary logistic regression model.

Results and Discussion

All palms established well except for two *Phoenix dactylifera* that died after planting, likely from inadequate irrigation; they tested negative for *Fusarium oxysporum* f. sp. *canariensis*. The remaining palms all established and began to produce new growth. FW symptoms and mortality were first noted in 2009 on *P. canariensis* followed by *P. reclinata* (Fig. 1) and *Washingtonia filifera*. By the fall of 2012 all *P. canariensis* and about half the *P. reclinata* and *W. filifera* had died (Table 1). None of the *P. roebelenii* or remaining *P. dactylifera* died. Fertilizer treatment did not significantly affect mortality. Similarly, fertilizer treatment did not affect growth of any species except *W. filifera*, which responded positively and equally to any fertilizer (data not shown).

Because no *Phoenix dactylifera* died from FW we feel confident in advocating this species as a replacement for *P. canariensis* that have died from FW. This finding is consistent with those of Priest and Letham (1996), who found *P. dactylifera* not to be susceptible to *Fusarium oxysporum* f. sp. *canariensis*. Also, we are able to corroborate Ohr (pers. comm.) and Summerell et al. (2001) that *Washingtonia filifera* is susceptible to *Fusarium oxysporum* f. sp. *canariensis*, at least under our experimental field conditions. We stress that we have never seen or verified *W. filifera* or *P. reclinata* dying from FW in the landscape, a fact that is somewhat puzzling because there is certainly ample opportunity for FW to spread from infected *P. canariensis* to these two species because the three species are frequently planted together in California. We also show that *Fusarium oxysporum* f. sp. *canariensis* can remain viable in fallow soil for at least 25 years and still infect some species of newly planted palms, which verifies the recommendation not to replant *P. canriensis* and other susceptible species of palms into the same site where a palm has died from *Fusarium oxysporum* f. sp. *canariensis*.

While not significant at the end of the study, the interaction of palm species and fertilizer source produced a few interesting results. Fertilizers containing nitrate were associated with more deaths from *Fusarium oxysporum* f. sp. *canariensis*, contradicting the results of Keim and Humphrey (1984) for *Hebe* sp., suggesting that another study is needed using more replication to verify the possible significance of this finding.

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