Below Ground Competitive Strategies:

THE ROOT OF THE MELALEUCA PROBLEM IN A SOUTH FLORIDA FLATWOODS

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Non-native plant species are able to out-compete native Florida plants in many habitats. We are learning about the mechanisms that explain just how that occurs. For instance, many populations of *Sapium sebiferum* (Chinese tallow) in the US allocate much more of their available energy to rapid growth than to defense mechanisms against insects, compared to populations in their native habitats (Rogers and Siemann 2002). Most of what we are learning involves either the physiology of the species, or the above ground morphology. Far fewer studies are looking at root competition - the real battleground beneath the surface where the other half of each plant lives.

How the Other Half Lives

The importance of root competition is nothing new—it was recognized as early as 1960 (Aspinall 1960; Harper 1961; Drew 1966; Baldwin 1972 and Atkinson 1973). Since as much as 50 percent of a plant lies below the soil surface, it might be expected that the same percent of the research on plants would focus on root physiology, morphology, distribution, and function. But we tend to study what is most easily seen, and roots are usually hidden (Waisel *et al.* 1996). Anyone who has tried to dig out the entire root system of even a small shrub can attest to the difficulties involved. Additionally, the very act of exposing plant roots is usually lethal to the plant—we can't easily watch root processes in place!

That hasn't kept researchers from learning how roots interact with other roots and with the soil environment. Most studies have focused on highly managed agricultural ecosystems, including studies in agroforestry (e.g., Livesley *et al.* 2002, Mickovski and Ennos 2002), row crops (e.g., Tuor and Froud-Williams 2002), rice (e.g., Gibson *et al.* 1999), and golf course putting greens (Kendrick and Danneberger 2002). Native plant communities have not been ignored. Seed production and germination success have been related to root competition in native plants (Allison 2002). Success of seedlings of certain tree species has been tied to root competition (Ammer 2002).

But more and more researchers are looking underground to answer questions about why our native plant communities are losing out to non-native species. Successful interspecific root competition (roots of two different species competing for the same limiting resource, such as nitrogen, phosphorous, water, etc.) is suspected as a primary reason why *Sapium sebiferum* (Chinese tallow) is able to outcompete native trees such as *Quercus virginiana, Acer negundo, Celtis laevigata, Salix nigra*, and *Liquidambar styraciflua, Taxodium distichum,* and *Quercus nuttallii* along certain parts of a hydrological gradient in Louisiana (Denslow and Battaglia 2002). Root competition may explain why native plants replanted into a *Pennisetum setaceum* (fountain grass) infestation in Hawaii were able to suppress the *P. setaceum* following certain site treatments (bulldozing, shade, outplanting), but not others (Cabin et al. 2002). We know that openings in the forest canopy are frequent sites for non-native plant invasion in Florida, and researchers have shown reduced root competition in some of these open areas (Cahill and Casper 2003).

> *Melaleuca quinquenervia* is classified as a Category I Species by the Florida Exotic Pest Plant Council (FLEPPC 2001). This definition refers to non-native invasive plants that are altering native plant communities in Florida by displacing native species, changing community structures or ecological functions, or hybridizing with natives.

Anyone who has traveled in south Florida is well aware of the widespread distribution of *Melaleuca quinquenervia*. As impressive as the number of trees present is the number of different types of habitat that this species has been able to invade. What is not as obvious is just why this plant is able to outcompete our native vegetation. Several studies have shown that *M. quinquenervia* produces a tremendous number of flowers and seeds (Meskimen 1962), and that seeds can be transported by both wind and water. So "how does *M. quinquenervia* get around?" is much better understood than "how is it able to occupy space faster than native plant species?"

Once *M. quinquenervia* forms a very dense canopy, it is logical to assume that the shade produced probably limits the types and amounts of native plants that can grow. However, it may be that *M. quinquenervia*'s roots allow it to first dominate a site and exploit soil resources. To study root competition in *M. quinquenervia*, we chose a flatwoods site near Lehigh Acres, Florida, where *M. quinquenervia* grows interspersed with the native grass *Andropogon virginicus* (broomsedge bluestem). The site has poorly drained soil, and is frequently flooded during the rainy season (summer), but also is subject to periodic drought—the water table varied from 3 feet below, to 4 inches above the soil surface during the time of our study. See what was going on underground between germination and canopy closure, we used the part of the site where *M. quinquenervia* had been removed with herbicide five years before our study started, but was re-invading from seeds. Thus we had trees that were from one to five years old.

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Photo 1. A soil trench method was used to measure the root distribution and density of field grown Melaleuca quinquenervia *trees in an age sequence.*

There are two major ways that *M. quinquenervia* can get the nutrients it needs when faced with competition from the native grass: it can simply do a better job of pulling water and nutrients from areas already occupied by the grass (termed "tolerance"), or it can avoid competition and send it's roots into parts of the soil horizon where the grass roots are not found (termed "avoidance").

Bare Root Stock

Examining roots in the soil is not the straightforward process it may seem. First you have to be able to identify which root belongs to which species (tree or grass), then you either have to map out the location of a sample of roots at varying depth, or develop some index of root location within the site. And since root size is an important indicator of where each species is putting its energy, volume measurements have to be taken as well.

We chose to use a soil trench method (photo 1) to find the roots, and an index method to compare the number and volume of the roots we found. We dug a trench approximately 3' wide by 3' deep x 16' long. The youngest *M. quinquenervia* trees were located at one end of the trench, and the oldest at the other. To get a better understanding of the variability within this site, we dug two more trenches (total of three). Roots were examined in three sections of each trench, corresponding to the youngest, middle-aged, and oldest trees along the trench line. Along the face of those specific sections of the trench, the location and diameter of each root found was recorded, and reported as the number of roots per square inch of trench face. Then a small amount of the trench face was removed, and the number of roots was counted and reported as the number of roots per cubic inch of soil volume. Each root was identified as either *M. quinquenervia* or *A. virginicus*.

This approach would give us a reasonable idea of where the roots of each species were located, and what proportion of the total root volume was located at each depth. This is important "historical" information of what has already happened at this site. It did not, however, let us see what happens when *M. quinquenervia* tries to move into an area already occupied by a native grass.

To accomplish that, we planted *A. virginicus* in plastic trays filled with soil collected from the study site (photo 2). Different amounts of phosphorous and nitrogen were added to the trays so we could see the effects of nutrient level on competitive ability. Those trays were then placed in the field where *M. quinquenervia* roots could grow into them.

The Square Root of Melaleuca Is...?

The first surprising result was that *M. quinquenervia* had higher root densities in the upper four inches of the soil trenches than did the native *A. virginicus* (Table 1). In other words, even one-year-old *M. quinquenervia* trees dominate the upper part of the root zone. By age five, *A. virginicus* roots were nearly absent from that upper zone. *A. virginicus* grew much better in the growth trays supplemented with additional nutrients - it may well be that *M. quinquenervia* is much more efficient at exploiting a low nutrient soil than is *A. virginicus*.

Not only were the root densities of *M. quinquenervia* much higher than *A. virginicus*, they were higher than what has been recorded for 20-year-old native southern pines (*Pinus elliottii*

Table 1. **Comparison of root length density values for 1- and 5-year-old Melaleuca trees and native grass *Andropogon virginicus* growing in the study site at Lehigh Acres, FL with those reported for a 20-year-old slash pine stand by Van Rees and Comerford (1986).**	*Melaleuca quinquenervia*	*Andropogon virginicus*	Compared with 20-year-old *Pinus elliottii* var. *densa* (Van Rees and Comerford 1986)
Root density* upper four inches of soil: -at the 1-year-old end of the trench -at the 5-year-old end of the trench	 3.9 7.8	 .52 .045	 4.68
Root density at (mid-level) - ten inches depth: -at the 1-year-old end of the trench -at the 5-year-old end of the trench	 1.57 3.12	 .026 .026	 .845
Root density at (below 16 inches) depth: -at the 1-year-old end of the trench -at the 5-year-old end of the trench	 .045 2.16	 0 0	 2.6

* expressed as: in of root/in^3 of soil volume

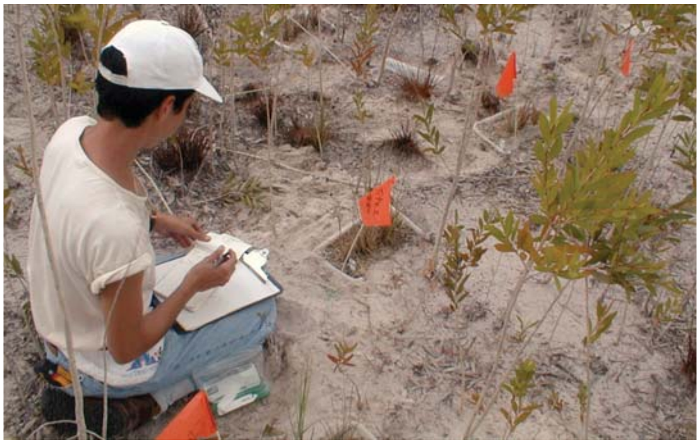

Photo 2. A growth tray study was carried out to address the ability of Melaleuca quinquenervia *to grow roots into soil volumes already occupied by* Andropogon virginicus *root systems.*

var. *densa*) growing on similar soils (Table 1; Van Rees and Comerford 1986).

The roots of *M. quinquenervia* aggressively invaded the *A. virginicus* in the growth trays, regardless of the head start provided to *A. virginicus*. Root densities for *A. virginicus* were substantial, but that did not keep *M. quinquenervia* roots from invading. It is clear that a) *A. virginicus* roots do not inhibit *M. quinquenervia* root development, and b) *M. quinquenervia* is able to tolerate the presence of *A. virginicus* roots — it does not have to avoid native grass roots by growing to an unoccupied portion of the root zone.

Wet Roots vs Dry Roots

Melaleuca rooting also was shaped by the water regime. Melaleuca roots were sampled during both wet and dry conditions. Root densities were lower in dry conditions and higher under wet conditions. The ability of melaleuca to produce high root densities in wet sites helps explain why it is commonly found in these areas. Melaleuca simply tolerates both wet and dry conditions very well.

Rooting Through the Muck

M. quinquenervia roots were present throughout the entire soil profile (Table 1), root density increased with age, and root densities were not negatively affected by the periodically high water table. Root densities for *A. virginicus* were much lower overall, and were zero below 16 inches. *M. quinquenervia*, in other words, not only is able to outcompete *A. virginicus* within the "grass root zone," but it is able to extend roots into sub-surface levels where *A. virginicus* does not grow. *M. quinquenervia* is able to both tolerate *and* avoid competition with *A. virginicus*.

The Root of the Problem - Conclusions

Plant competition is an important factor influencing plant invasion and in predicting the conditions under which a new species can enter a soil compartment (Connell 1983, Fowler 1986, MacArthur and Wilson 1967, Schoener 1983, Strong et al. 1986). The results of this study showed that *M. quinquenervia* is

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an excellent belowground competitor, able to both tolerate and avoid competition from native species. It grows well in wet and dry soils, and can invade soil of high and low fertility. *M. quinquenervia* roots can rapidly invade soil compartments with pre-established, vigorously growing, native *A. virginicus*, and also unoccupied soils. *M. quinquenervia* trees are able to develop greater root densities than those of native vegetation that grow in the same soil conditions. All of these competitive strategies help to explain Melaleuca's enormous success as an invader of flatwoods in south Florida.

For more information on this study, contact Isabel Lopez-Zamora at ilopez@ufl.edu

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