The Land Manager's Handbook on Integrated Pest Management of *Melaleuca quinquenervia*

A product of the TAME Melaleuca Area-wide IPM project

Acknowledgments

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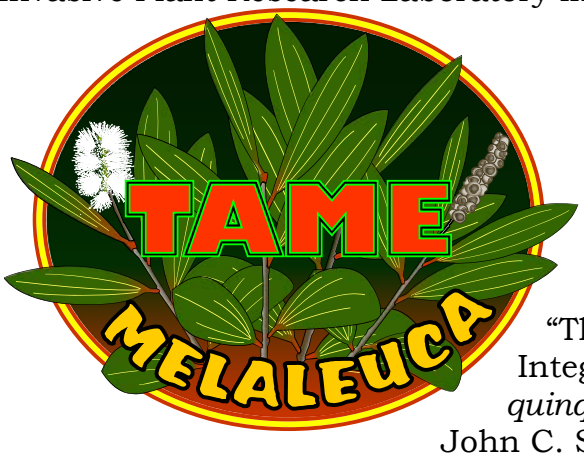

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National Audubon Society

The Nature Conservancy

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Preface

Dear Reader:

If you have this handbook in your possession you probably have an interest in removing or controlling melaleuca (*Melaleuca quinquenervia*). Whether you're a professional needing to understand the details or a curious observer, you will find something of value here.

The melaleuca control effort in Florida began more than 15 years ago with the initiation of the Melaleuca Management Plan. Since then, numerous methods have been used to remove or suppress melaleuca from the natural and developed areas of South Florida, with varying levels of success.

The purpose of this handbook is to provide information on the most current, effective, affordable and ecologically sustainable methods for controlling melaleuca. We've tried to pull together as much data as possible into one comprehensive collection so you can find the information you need, when you need it. Although written for land managers, others such as educators, students, and even homeowners should find the information useful.

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Introduction

Invasion in Florida

Melaleuca, scientific name *Melaleuca quinquenervia* (Cavanilles) S.T. Blake (Myrtacaea), is a notoriously aggressive exotic invasive plant in Florida. Native to Australia, it was brought to Florida as an ornamental in the late 1800s. Many of the environmental conditions and habitats of Florida are similar to those of melaleuca's native range in Australia, but without the insects, plant diseases, and other natural enemies to keep the tree in check. As a result, melaleuca grew quickly and robustly in its new home and people looked for ways to make use of its productivity. It was tested as a timber crop, wind break, soil stabilizer, and even as a means to dry up the wetlands of the Everglades. This led to it being widely planted on both coasts of the state and along inland waterways.

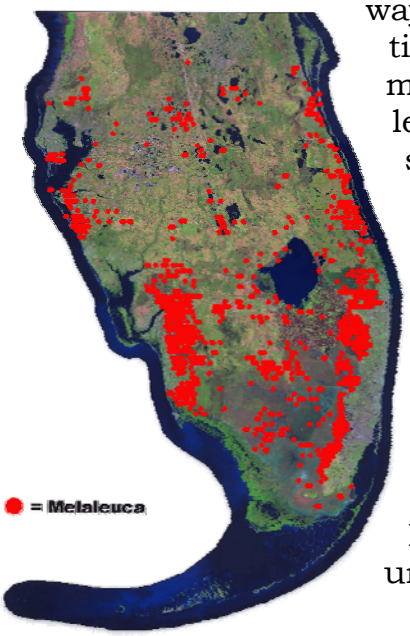


Figure 1. Map of melaleuca distribution in South Florida

Melaleuca soon spread from intentional plantings and became naturalized. It was first reported in Everglades National Park in 1967, and by 1993 was estimated to cover almost 500,000 acres of wetland, riparian and, to a lesser degree, agricultural systems in the southern third of the state. Eventually, melaleuca colonized up to 20 percent of all natural land south of Lake Okeechobee (see Figure 1 and Figure 2), much of which comprises the unique and prized greater Everglades ecosystem.

Melaleuca is competitively superior to most other vegetation in southern Florida. It flowers multiple times per year and produces copious amounts of seeds. Trees grow quickly and readily re-sprout after being damaged. Melaleuca is well adapted to fire and has a dense root system that adapts to flooded or dry conditions. With these advantages, infestations quickly develop into dense, monospecific forests that displace native vegetation and thereby degrade wildlife habitat. Other changes brought on by melaleuca invasion include elevated soil levels which can affect water flow patterns, and altered fire regimes. Economic losses to melaleuca infestations are estimated to be hundreds of millions of dollars. This includes losses in wetland function, rangeland productivity, recreation, fire damage to property and infrastructure, and increased fire control costs.

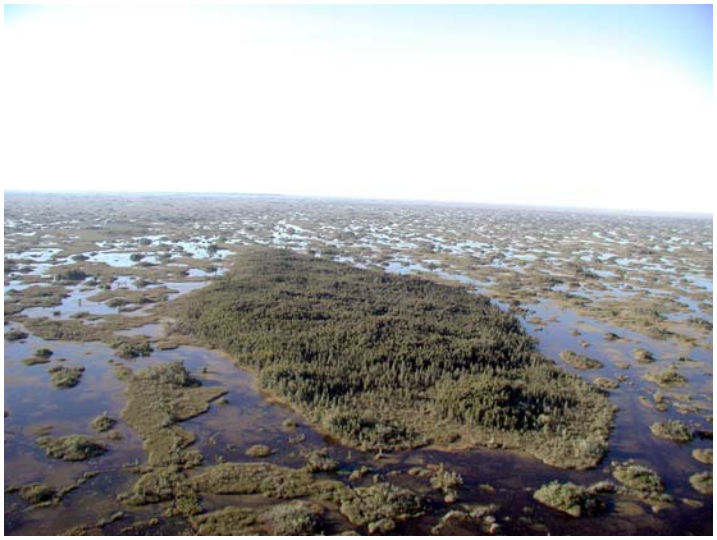


Figure 2. Melaleuca infestation in the Everglades

As a result of the economic and environmental risks posed by melaleuca invasions, the tree is now listed by federal and state authorities as a noxious weed, making it illegal to possess, cultivate, sell, or transport in the United States. Melaleuca management is also a high priority for many resource managers and land owners in the state, with government agencies alone dedicating more than $35 million to it to date. Consequently melaleuca coverage on public lands in the state has been reduced, but melaleuca remains a continuing threat on both public and private lands.

Management Challenges and Approaches

Not only do melaleuca trees flower frequently and produce copious amounts of seeds per year, but the seed capsules tend to stay closed on the tree year after year. A single mature tree may hold as many as 50 million seeds in its canopy. When the tree experiences severe stress such as caused by fire, drought, physical damage or herbicide application, the vascular tissue function is interrupted which triggers the seed capsules to open simultaneously, releasing millions of tiny seeds at once. Melaleuca seeds can germinate quickly and seedlings grow rapidly, resulting in an even-aged thicket of small trees where once only a single tree stood (Figure 3).

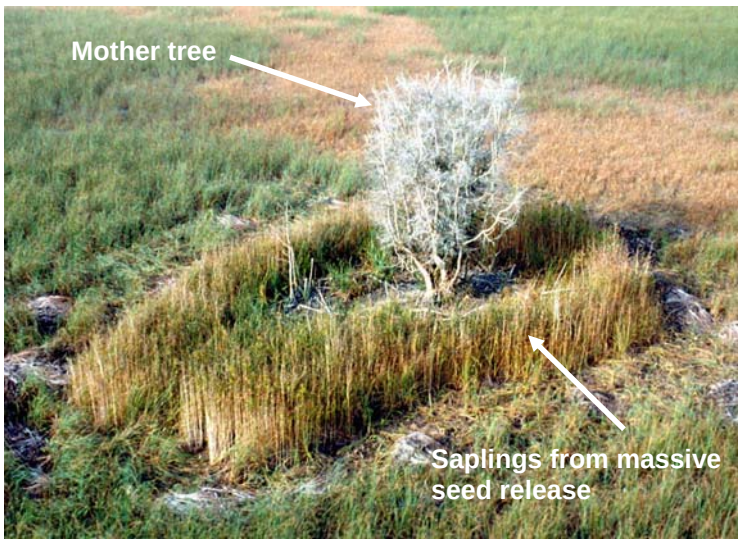


Figure 3. Thicket produced by a massive seed release

As a long lived, evergreen tree, melaleuca has an extensive root system for water uptake and nutrient storage. When melaleuca is damaged, below-ground nutrient reserves support healthy regeneration. In addition, melaleuca trunks and stems are lined with epicormic buds that easily sprout when apical buds are damaged or removed.

Therefore if a melaleuca tree is trimmed or cut down without killing the remaining trunk or stump, it re-grows with more branches and biomass than before.

Successful, long-term management of melaleuca therefore requires both removing existing infestations and reducing the tree's reproductive and regenerative abilities in order to prevent new and renewed infestations.

In 1990, the Florida Exotic Pest Plant Council and the South Florida Water Management District convened a task force of federal, state and local land managers, scientists, and others. Their charge was to develop a comprehensive, interagency plan for managing melaleuca. The result was the first Melaleuca Management Plan. In the ten years since its original publication, this Plan and its two subsequent editions have served as a framework for agencies managing or seeking to protect natural areas infested by melaleuca. The recommended approach is an integrated one that makes use of all available control tactics to kill existing stands as well as the seedlings and re-sprouts that emerge after initial treatments. Control tactics included in the Plan are mechanical, herbicidal and physical. And although biological control for melaleuca was not available at the time the Plan was written, the Plan did recognize it as an important component of long-term management.

Quick Facts about Melaleuca:

- Melaleuca was brought to Florida as an ornamental plant in the late 1800s.
- In the 1930s, melaleuca seeds were scattered by airplane over the Everglades in an effort to drain "useless swamps."
- Melaleuca has become abundant in wet pine flatwoods, sawgrass marshes and prairies, and cypress swamps. It prefers seasonally wet sites but also flourishes in standing water and well-drained uplands.
- Melaleuca quickly forms dense, impenetrable stands of tall trees (to 100 feet) that completely shade out and displace native vegetation.
- Melaleuca can grow 3-6 feet per year and one tree can produce as many as 20 million seeds annually.
- Melaleuca is well adapted to fire. In fact, fire helps release seeds as well as disperse the seeds in wind generated by a hot fire.
- Melaleuca, and other invasive exotic plants, are a serious threat to the natural systems of South Florida, including the Everglades.

Since first publication of the Melaleuca Management Plan, mechanical, herbicidal and physical techniques for killing melaleuca have been refined and a biological control program has been implemented with the release of two leaf-feeding insects. This manual contains current integrated techniques available to professional managers and applicators for long-term melaleuca suppression in natural areas, rights of way, and agricultural lands.

Safety

Within this document you will see the following warning and caution icons:

Warnings inform you of dangers that can cause injury to you. Cautions inform you of dangers to the environment, equipment, structures, and so on.

General rules regarding safety:

- Always read and follow the instructions on labels.
- Always read and follow the instructions in the operator's manual.
- Wear appropriate protective clothing.
- Use common sense when working around large trees, with power equipment and herbicides.

Heavy equipment often holds and transports seeds in numerous crevices. Land managers should ask equipment owners to thoroughly pressure wash their equipment before coming on site. Prevention is easier and cheaper than eradication, and is a fundamental component of any Integrated Pest Management program.

Inexperienced persons should not attempt to cut down large trees without experienced supervision.

Chainsaw safety cannot be over-emphasized. There are no restrictions on purchasing chainsaws, and little training is available. While chainsaws are inherently dangerous, both the felling of the tree and the trimming of the downed tree are equally risky. The owner's manual gives details on proper use of the chainsaw as well as cutting down trees. ***Read the owner's manual and follow the directions.***

Melaleuca Identification and Biology

The first step in controlling any pest is to properly identify it. Melaleuca is an evergreen tree that averages 50 to 70 feet in height, but may reach heights of 100 feet (Figure 4). Trees that grow in open areas often have multiple trunks.

Figure 4. Individual melaleuca tree

In wetland areas, melaleuca commonly forms dense stands of thin trees with as many as 132,000 stems per acre (Figure 5). Trees that grow in these dense monocultures generally lack branches on the lower two thirds of the tree.

Figure 5. Stand of dense melaleuca trees

The root system of melaleuca is well adapted to fluctuating water levels. Dense roots near the soil surface are complemented by abundant vertical sinker roots that extend at least to the water table's deepest annual level. Melaleuca has the capacity to produce a profusion of adventitious roots shortly after flooding, which supply oxygen to the flooded portion of the tree.

Bark

The most distinguishing characteristic of melaleuca is its thick, spongy, papery bark that peels easily – hence its common name in Australia, the paperbark tree (Figure 6 and Figure 7). Bark makes up about 20% of the stem volume. The bark color ranges from dull white to pale cinnamon.

Figure 6. Distinctive bark of melaleuca

Figure 7. Close-up of melaleuca bark

Leaves

Melaleuca's grayish-green leaves are oblong with five parallel veins and smell of camphor when crushed. The leaves when mature are flat, stiff, and leathery.

Trees growing in moist environments tend to hold their leaves longer than trees growing in drier environments. Leachates from the leaf litter have slowed germination of slash pine and cypress seedlings, perhaps lending another competitive factor to melaleuca's invasive abilities in Florida.

Also, young saplings and seedlings respond to inundation by changing leaf shapes. Leaves become more linear when meristems are deeply flooded, while a rounded leaf forms when the submerged meristem is near the water surface. These water-level induced leaf forms may enable better light or nutrient utilization, or help the plants survive flooding.

Figure 8. Melaleuca leaves – new growth

Figure 9. Mature melaleuca leaves

Flowers

Melaleuca flowers are white and bottlebrush-like (Figure 10 and Figure 11). Melaleuca trees can bloom when as young as three years of age and as many as five times per year. Flowering takes place as branch portions change into flowering spikes. This conversion is preceded and succeeded by a "resting" phase indicated by a scaly zone on the branch.

Figure 10. Melaleuca in bloom

In Florida, main flowering periods are fall and winter. Melaleuca could be considered a 'winter' tree. While some flowering and growth occur year-round, the main flowering season in South Florida is November through January, with bursts of vegetative growth generally occurring after flowering and peaking in January and February. However, in wet years, both flowering and new growth periods can extend in response to greater water availability. In a heavy blooming year, flowering season may start earlier in July and August and extend longer into March and April with several flowering cycles.

Figure 11. Melaleuca flowers

Flowers often cluster in trios. Each ovary consists of three parts surrounded by a calyx tube and ten hairy glandular tube outgrowths. These glands secrete nectar, which collects in the basal floral cavity. A single flower consists of six to ten stamens that are opposite each of five sepals and five white petals. A flower cluster (Figure 11) contains dozens of flowers.

Figure 12. Insects pollinating melaleuca flowers

Insects (usually bees) pollinate the flowers. Seed fertility is low.

Seeds and Seed Germination

Flowers givindexe rise to clusters of woody seed capsules along the stem (Figure 13). Melaleuca seed capsules are cylindrical, thick-walled containers about 3/8 inch in diameter (Figure 14). Each capsule contains up to 300 tiny brown seeds (Figure 15). A single tree can store as many as 50 million seeds (Figure 16). Most seeds germinate within two years, but seeds can remain viable for up to ten years. Trees living in permanently flooded habitats hold a greater number of seed capsules than trees living in dry or seasonally flooded habitats.

Figure 13. Melaleuca seed capsules

Melaleuca produces a light and constant seed rain but when stressed by fire, herbicides, storms, etc., it will produce a massive seed release. Seed release is caused by disruption of the vascular connections to the capsule bearing branches.

Viability of seeds varies with tree age with the youngest and oldest trees producing fewer viable seeds. Seeds germinate in or on moist soils, usually within a few days of wetting, and may remain viable up to six months under water or in wet soils. Also, seeds may germinate while completely inundated. Seedlings less than several weeks or months old may die from fire or if soils are dry. However, with age, seedlings are able to withstand extreme conditions ranging from fire to total immersion for up to six months.

Figure 14. Melaleuca seed capsules with seeds exposed

Timing of fire, frost, drought, herbicide application, stem damage, and flooding events can determine whether melaleuca seed release events lead to successful establishment and spread.

Figure 15. Melaleuca seeds – a single capsule can contain up to 300 seeds

Figure 16. One mature tree can store more than 50 million seeds

Herbicidal Control of Melaleuca

Herbicides are used for integrated melaleuca management to kill existing trees. Products with the herbicide active ingredients glyphosate, imazapyr, triclopyr, and hexazinone are used depending on the method of application and other factors, particularly the presence of non-target vegetation in the application area. Four application methods are used depending on extent of the population and other factors: foliar, hack and squirt, cut stump, and basal (applied to the soil). Backpack sprayers, hand-held spray bottles, dropper bottles, and sprayers mounted on helicopters, trucks, and all-terrain vehicles, are used to apply herbicide. Various adjuvants may be added to the spray mixture to aid or enhance the action of the herbicide or the physical characteristics of the mixture. Adding a marker dye to the spray solution helps to see where herbicide was applied.

All herbicides used for melaleuca control have very low toxicity to wildlife and low risk to humans. Because of repeated exposure, applicators are required to wear personal protective equipment, which is described on the herbicide manufacturer's label, when mixing, loading, or applying herbicides. Glyphosate, imazapyr, triclopyr, and hexazinone differ in their chemical characteristics and threat to non-target vegetation, which will influence the choice of herbicide for each application site.

Another consideration when choosing the appropriate herbicide is the presence or absence of standing water on a site when the herbicide application is conducted because some herbicide products are registered for application over water while some are not. Additional information on herbicide characteristics and application techniques can be found in IFAS publication SP 295, "Natural Area Weed Management", which can be ordered by calling the IFAS Extension Bookstore at 1-800-226-1764 or at http://ifasbooks.ufl.edu.

Herbicides

Glyphosate is a broad-spectrum, water-soluble herbicide that kills plants by inhibiting synthesis of amino acids. Because of its solubility characteristics, glyphosate requires the addition of a surfactant to the spray mixture to aid in foliar uptake. Some glyphosate-containing products (Roundup Pro, Accord XRT, Glyphosate Herbicide VMF, Touchdown Pro, Roundup Weed & Grass Killer Super Concentrate) contain surfactant that is added by the manufacturer, while surfactant must be added to other products (Rodeo, Aquamaster, Aquaneat, Aquapro, Accord Concentrate) by the user according to label instructions.

When applied to the leaves of plants or directly into the plants (as in cut surface applications), glyphosate translocates throughout the plant. Glyphosate is not absorbed by plant roots because it is adsorbed strongly once it comes in contact with the soil. Therefore, damage to non-target vegetation as a result of root uptake is minimal. Care must be used to avoid contact of the herbicide spray with the leaves and green stems of non-target plants.

Imazapyr (Arsenal, Habitat) is a broad-spectrum, water-soluble herbicide that kills plants by inhibiting synthesis of amino acids. It differs from glyphosate in that it is taken up more rapidly and readily by plant leaves and is also readily absorbed from the soil by plant roots. It also remains active in the soil for up to three years. Application of imazapyr can cause damage to non-target plants if it contacts their leaves or enters the soil and comes into contact with their roots in sufficient quantity.

Triclopyr affects many woody plant species and broadleaf herbaceous species but grass species are relatively tolerant to it. It kills plants by disrupting tissue development and other physiological processes. It is absorbed primarily through plant leaves and to some extent by plant roots. Damage to non-target vegetation as a result of root uptake is more likely in porous, low organic matter-containing soils.

Triclopyr is manufactured as the amine salt (Garlon 3A, Renovate 3) or ester (Garlon 4, Pathfinder II). The amine salt is water soluble and the ester is oil soluble. The ester-containing product, Garlon 4 contains emulsifiers so that it can be mixed with water in low concentrations. Both the amine and ester are absorbed through leaf tissues but a surfactant is necessary to aid uptake of the amine. Neither amine nor ester is absorbed effectively by melaleuca leaves.

Hexazinone is a broad spectrum, water soluble herbicide that kills plants by inhibiting photosynthesis. It is predominantly absorbed by plant roots with negligible uptake by leaves. It is manufactured as a liquid (Velpar L), dry flowable (Velpar DF) and ultra-low-weight granule (Velpar ULW). Like imazapyr, it can kill sensitive non-target woody vegetation if it comes in contact with their roots. Cypress (*Taxodium* spp.) and pine (*Pinus* spp.) are tolerant. Hexazinone has a typical half life in soils of 90 days but disappears from porous soils more rapidly through leaching. Shallow rooted herbaceous species, particularly grasses, will recover in treated sites. Hexazinone can only be used on dry sites.

Application Methods

Foliar applications for melaleuca control are mainly used for treating sapling trees less than four feet tall that cannot be hand-pulled. Additionally, large-area applications are made to mature trees where little non-target vegetation exists. Saplings are treated with herbicide diluted in water as a low volume application using a backpack or hand-held equipment (Figure 17) with one of the following:

1) Glyphosate solution equivalent to 5% product that contains 3 to 4 pounds per gallon glyphosate acid and 1% imazapyr product that contains 2 pounds imazapyr acid per gallon, or

2) 3% glyphosate product solution plus 3% imazapyr product solution. Surfactant must be added to the spray mixture if it is not already contained in the products used. Solution containing 5% glyphosate product and surfactant alone can be used but some re-sprouting may occur that will require follow-up treatment. Surfactant products that contain methylated seed oil are most effective.

Figure 17. Foliar application using hand-held equipment

For broadcast applications to control large areas of mature trees, 3 pounds glyphosate acid per acre plus 1.5 pounds imazapyr acid per acre (e.g. 6 pints Rodeo plus 6 pints Habitat), plus methylated seed oil surfactant are applied by helicopter (Figure 18). For complete coverage, the application is made in at least two perpendicular passes.

Figure 18. Foliar application using a helicopter

Hack and squirt applications (also called frill and girdle) are used for outlier trees or for large stands where aerial application is not desirable. Hack and squirt is much more labor intensive than aerial application but can reduce non-target damage. A machete is used to cut through the bark deep enough to expose the living tissue just inside the bark (cambium layer) (Figure 19). Cuts are made in a downward direction so the severed bark remains to contain the herbicide mixture. Herbicide solution (diluted in water) of 25% product that contains 3 to 4 pounds per gallon glyphosate acid and 25% imazapyr product that contains 2 pounds imazapyr acid per gallon (Habitat or Arsenal) is applied to the girdle in sufficient quantity to thoroughly wet the tissue. A hand-held spray bottle is usually used to apply the herbicide (Figure 20).

Figure 19. Typical hack and squirt application

Figure 20. Hack and squirt technique

Damage to non-target vegetation can occur if the imazapyr is washed from the girdle to the soil. A solution of 50% to 100% glyphosate product alone can be used but tree mortality is less consistent.

When hacking and squirting trees with multiple trunks care must be taken that all the trunks are completely girdled to prevent re-growth (Figure 21).

Figure 21. Hack and squirt on trees with multiple trunks

Cut stump application is the most labor intensive application method and is only used when it is not desirable, for reasons of safety or aesthetics, to leave dead trees standing. Trees, depending on size, are felled with a brush lopper, hand-saw, or chainsaw (see the section on Using a Chainsaw, page 21) as close to the ground as possible and as level as possible (Figure 22). Herbicide will tend to run off slanting cuts made with a machete, and mortality will be less consistent, therefore, using machetes is not recommended. Sawdust, which can absorb herbicide and prevent it from entering the stump, should be brushed from the cut surface before applying herbicide. Herbicide solution should be concentrated just inside the bark, where the living tissue of the tree is located (Figure 22). A 10% to 25% solution of product that contains 2 pounds imazapyr acid per gallon (Habitat or Arsenal) is most often used. A 50% solution or 100% of product that contains 3 to 4 pounds per gallon glyphosate acid is also effective and can be used to minimize potential non-target damage.

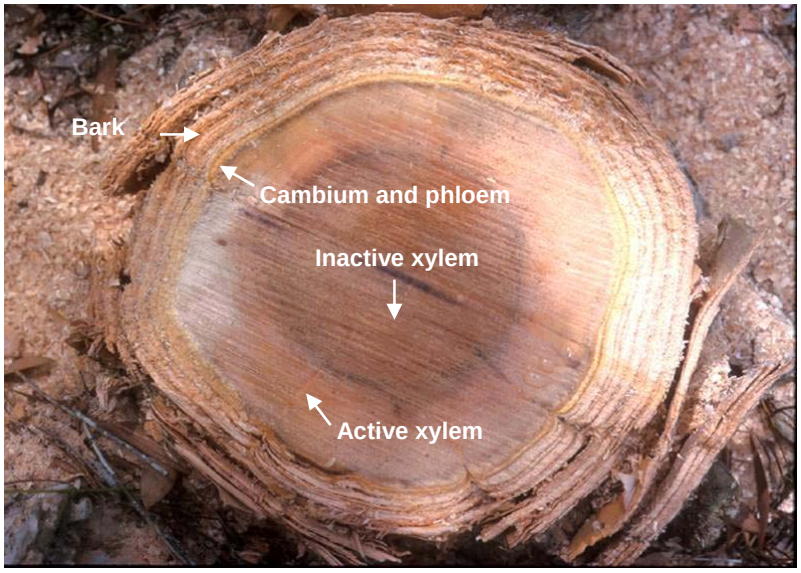


Figure 22. Cut stump detail

Herbicide solution should be applied as soon after cutting as possible. Hand-held spray bottles or dropper bottles can be used to apply the herbicide solution. Dropper bottles are very effective for concentrating the herbicide solution to the cambium area (Figure 22). If stumps are not cut close to the ground, re-sprouting is more likely to occur, especially with glyphosate containing products. Triclopyr products are less consistent than those containing glyphosate or imazapyr and are only recommended as an alternative to homeowners with a small number of trees, because these products are available in small quantities at retail garden stores.

Basal (soil) applications of 3 pounds hexazinone active ingredient per acre are applied for melaleuca control. Liquid (Velpar L) and dry flowable (Velpar DF) products are applied by helicopter for large area treatments. Because the herbicide is applied over the tree canopy and foliage, these applications could be considered as foliar applications. However, it is described here because herbicidal activity probably occurs after the herbicide reaches the soil and is taken up by roots. Granular hexazinone (Velpar ULW) is applied with ground equipment using a specialized blower.

Mechanical Control of Melaleuca

Mechanical removal of melaleuca is done with logging or heavy-duty mowing equipment, and works well in the initial elimination of mature trees. Seedlings, saplings, and remaining stumps require herbicide application. Mechanical removal using heavy equipment is not appropriate for most natural areas where melaleuca occurs, because of disturbance to soil and non-target vegetation. However, this method still has an important role in the integrated management of melaleuca, and can generally be used for:

- land clearing for development
- canals, roadsides, and utilities rights-of-way
- some limited use in natural areas

Positive aspects of mechanical clearing include:

- quick results
- no trees left standing

Negative aspects of mechanical clearing include:

- non-target damage to native plants
- rutting (especially in wet sites)
- soil compaction
- usually requires herbicide application and follow-up treatments
- costly

Like many other species, melaleuca trees will usually re-grow after being cut (Figure 23). To prevent re-growth, treat the stumps by either spraying with herbicide or grinding below the soil surface with a stump grinder. Although it has not yet been formally evaluated, grinding the stump should prevent re-growth. Refer to the section on Application Methods, page 13, for additional information on cut stump applications.

Figure 23. Stump re-growth

There are several types of machines that are useful for the mechanical removal of melaleuca. Your choice of machinery will vary depending on site condition, cost, and desired results.

Using Heavy Equipment

Heavy equipment used for clearing melaleuca comes in all shapes and sizes and certain types may be better than others depending on the area being cleared, size of the trees, soil condition, and so on. The remainder of this section describes some of the more common equipment. The tables on page 20 provide a comparison of the most common equipment.

> **Caution**
>
> Heavy equipment often holds and transports seeds in numerous crevices. Land managers should ask equipment owners to thoroughly pressure wash their equipment before coming on site. Prevention is easier and cheaper than eradication, and is a fundamental component of any Integrated Pest Management program.

Feller-bunchers (Figure 24) first grasp then cut trees, allowing for easy stacking. The feller-buncher head consists of grappling devices and a cutter. The operator moves the machine into position in front of a tree and maneuvers the felling head to the tree trunk. The grapplers wrap around the tree and the cutter severs the trunk from the roots. A second set of arms, known as accumulator arms, hold the tree (or trees) in a bunch until the volume or weight capacity is reached. The cut trees are then laid horizontally on the ground.

Figure 24. Feller-buncher

Feller-buncher cutting heads consist of either a saw (disc or chain) or shears. Saws leave a smoother stump surface than shears, which facilitates herbicide uptake (melaleuca trees readily re-grow from stumps, so herbicide application is recommended). Disc saws are usually preferred over chainsaws because they require less-frequent sharpening. Regardless, saw blades should be sharp because dull teeth mangle stumps, making adequate herbicide application and uptake difficult. An herbicide sprayer can be mounted on the head to facilitate stump spraying.

Feller-buncher heads are mounted on either a tracked skid-steer (also known as a multi-terrain loader) excavator or rubber-wheeled articulating loader. Feller-bunchers on skid-steers or loaders range from four feet wide to more than eight feet wide, with the smaller models resulting in less damage to native vegetation.

If soil disturbance and compaction are a concern, feller-bunchers have the advantage of being able to use the logs to create a platform from which to operate. In a technique called mat-logging, the trees are laid down and the feller-buncher is driven up on the downed logs. This technique works well with all feller-bunchers, but especially those attached to excavators. Excavator-mounted feller-bunchers are also ideal for reaching into particularly wet sites (e.g. cypress swamps) or where steep slopes exist (e.g. along levees).

Wheeled vehicles are more maneuverable and can do the same amount of work in less time than tracked vehicles resulting in lower costs. Machine size can also influence cost. Large machines may cost more per hour, but may be more efficient on large sites. Small machines are limited to smaller-sized areas (less than 5 acres) and smaller trees (less than 14 inches).

The advantages of feller-bunchers and stacking trunks into piles include:

- If trees are left on site, consolidating trees (along with their seeds) limits the sprouting of seedlings to a single area.
- Stacking does not give melaleuca seedlings the bare soil needed for establishment. Consequently, while seeds from the trees may germinate, most will not become established.
- Stacking is less unsightly than scattered logs.
- When removing trees from the site, they are easier to load onto trucks when collected in a single location.
- Finally, if trees are to be moved, feller-bunchers might not disturb the soil as much as equipment that drags the trees.

Figure 25. Brontosaurus

Forestry mowers or **mulching heads** attach to excavators or four-wheeled loaders and mow trees to the ground, leaving behind melaleuca mulch. Mowers mounted on excavators (also called track-hoes) are lowered onto trees from above with the use of an articulating arm, while those mounted on wheeled or tracked loaders mow the tree from the side, pushing the trees over before mulching them. Production and efficiency vary according to mower type and size, power plant type, and horsepower. Before contracting with a company to mechanically clear melaleuca, land managers should know the size of the largest trees to ensure the equipment used can handle the task.

There are several manufactures of mowers for excavators, and each makes different-sized heads. Smaller brush cutter heads, such as the Hydroax mower, are only suitable for small melaleuca trees. Hydroax mowers were more common several years ago, and are rarely used today. Slightly larger mowers, such as the Brontosaurus (Figure 25), are sometimes referred to as mulching mowers. Well-known in South Florida, these mowers work well for most trees but cannot handle melaleuca trees larger than 2 feet in diameter.

Larger mowers are often called chippers, because they chip the tree as they mow it. Chipping heads can handle larger melaleuca trees than mowing heads. For example, the Denis Cimaf DAH 150 (Figure 26), when mounted on a Komatsu 30-ton excavator, can handle melaleuca up to 4 feet in diameter. Most chippers and mowers cut the trunk to ground level, while the Clear-More chipper/stumper actually cuts the trunk into the ground, destroying the stump in the process. Grinding the stump, either with a Clear-More or stump grinder, may prevent any re-growth without herbicide being applied.

Figure 26. Denis Cimaf DAH 150 mowing head

Some mulching mowers or brush cutters attached to four-wheeled loaders are good for very large jobs. With machines such as the Barko chipper (Figure 27), a frame is built around a cutter head, and trees are pushed over and mulched at the same time.

Four-wheeled loaders with mulching mowers or brush cutters attached work well when clearing acres of melaleuca, or for making fire lines around wildfires. One drawback of these mowers is their lack of selectivity, a point lessened with melaleuca monocultures. Front-attacking mowers can be attached to either rubber- or steel-tracked vehicles.

Figure 27. Barko chipper

Mowers, chippers and feller-bunchers attached to excavators are generally more selective around native vegetation than are wheeled tractors. However, because each tree is mulched from the top down, the time required to clear a site with a mower on an excavator can be long if tree density is high.

Equipment Comparison Tables

Melaleuca treatment equipment selection requires:

- Knowledge of the trees (How many are there? What size are they?)
- Knowledge of the terrain (How large an area needs treatment? How accessible is it? How environmentally sensitive is it?)

Equipment names and terminology vary widely but generally equipment is a combination of some type of head which actually cuts, chips, or grinds (Table 1) and a tractor (Table 2).

Table 1 Equipment Heads

HEAD TYPE	TREATABLE TREE SIZE[1] (diameter)	RELATIVE RISK OF NON-TARGET DAMAGE	NEED FOR FOLLOW-UP TREATMENT ON STUMPS
Feller-buncher	Up to 36 inches	Low	Yes[2]
Brush mower	Seedlings and saplings	Highest	Yes
Forestry mower	Up to 48 inches	High	Yes[3]
Stump Grinder	No limit	Lowest	No, if stumps are ground below soil level

Table 2 Tractor Types

TRACTOR TYPE	RELATIVE RISK OF NON-TARGET DAMAGE	RISK OF SOIL COMPACTION[5,6]
Wheeled	Low	Low
Tracked	High	High
Excavator[4]	Lowest	Highest

Notes:

[1] May depend on the manufacturer.
[2] Some units can treat the stump with herbicide after cutting.
[3] Some equipment manufacturers claim that a deep layer of mulch left by the equipment is sufficient to restrict stump re-growth and seedling recruitment.
[4] Excavators can be tracked or wheeled.
[5] Soil compaction is largely a function of machine size and operator skill level.
[6] Feller-buncher head allows use of mat-logging which lowers soil compaction.

Using a Chainsaw

Often the easiest way to control melaleuca is to cut it down with a chainsaw. This is most advantageous:

- when there are only a few trees
- when using other equipment is prohibitive
- when an area is inaccessible by heavy equipment
- when in environmentally sensitive areas where heavy equipment or herbicides would be inappropriate.

WARNING

Chainsaw safety cannot be over-emphasized. There are no restrictions on purchasing chainsaws, and little training is available. While chainsaws are inherently dangerous, both the felling of the tree and the trimming of the downed tree are equally risky. The owner's manual gives details on proper use of the chainsaw, as well as cutting down trees. ***Read the owner's manual and follow the directions.***

Before cutting down a tree you must carefully consider all factors which affect the process, such as:

- direction the tree will fall
- which way the tree is leaning
- slope of the ground
- unusual limb structures that might affect the fall of the tree
- dead or broken branches that could come loose
- any surrounding objects
- speed and direction of the wind

Figure 28. Using a chainsaw to cut melaleuca

Cut the trees as close to the ground as possible. Grind the stumps below the soil surface or treat the stumps as described in the section on herbicides (on page 11).

WARNING

Inexperienced persons should not attempt to cut down large trees without experienced supervision.

Other Factors to Consider

Soil disturbances create unwanted ecological impacts, as well as being aesthetically unpleasing. Deep ruts, resulting from working in wet soil and often a careless operator, can last for decades. Heavy machinery can damage the roots of native trees, making the trees susceptible to attacks from disease and insects. Soil disturbances create openings for new plants to colonize, and invasive species like melaleuca are often the first to exploit disturbed areas. Once established, these colonizers can prevent native species from re-inhabiting the disturbed areas.

Heavy equipment can compact the soil, which can inhibit oxygen and water from getting into the ground, limiting plant growth. Tracked vehicles tend to have lower ground pressure per square inch than wheeled vehicles, resulting in less soil compaction. However, high-flotation tires can be mounted on wheeled loaders, and some of these vehicles even have fewer pounds per square inch than human feet. A drawback of these wide tires is that they widen the vehicle, which can lead to more damage on surrounding trees and shrubs. In fact, some of these low-pressure tires make the machine so wide it cannot be towed on the highway; the wheels must be changed after it arrives at the field site. While natural areas can take years to recover from significant soil disturbance, these effects can be minimized with a conscientious machine operator.

While mulch may be useful for aesthetic purposes, it also has a practical purpose. The layer of mulch greatly reduces the probability of seedling reinvasion. The use of different equipment results in different-sized mulch, so equipment should be considered if the size of mulch pieces is a factor. For example, the Brontosaurus leaves behind a relatively coarse mulch (some pieces may be larger than a foot in length). Smaller mulch may be more aesthetically pleasing if the site will be landscaped. If the site will be replanted with vegetation after mowing, several inches of coarse mulch makes replanting more difficult. Mulch size is also influenced by the machine's operator, as it can be chopped smaller, but this takes more time.

Mechanically controlling melaleuca requires transporting heavy machinery, and a minimum number of acres may be required to justify the effort. The time required to clear an acre generally runs from one-half to two days, and varies according to machinery, tree density, tree size, and site conditions.

Biological Control of Melaleuca

Biological control is the use of living natural enemies to control pests. It does not eradicate the pest, but is intended to decrease population densities to below economically or environmentally significant levels. Classical biological control is the importation and release of biological control agents into an area in which they are not already present, with intent to establish a permanent population. This involves searching for natural enemies in the home range of the pest. Once potential biological control agents are identified, they go through a long and rigorous quarantine-based screening process to make sure they feed and reproduce only on the target pest, and that they cause the desired type of damage to the pest.

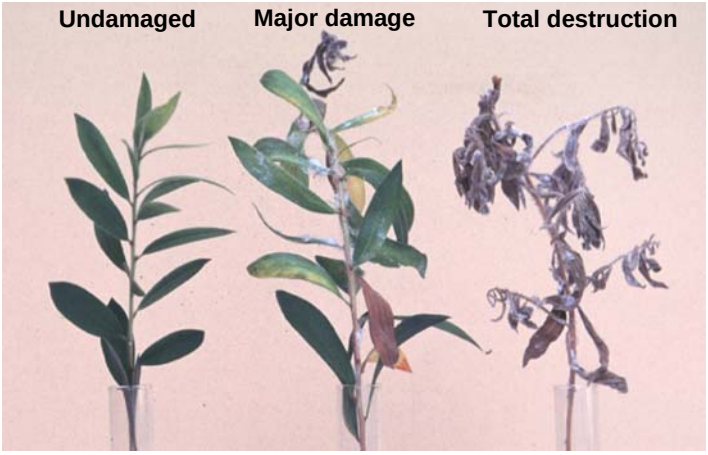


Figure 29. Damage caused by melaleuca psyllids

In the case of melaleuca, the search for natural enemies began in 1986 in Australia, where more than 450 species of insects and pathogens were found attacking melaleuca. Natural enemies that interfered with melaleuca growth and reproduction were chosen for further testing of host-specificity, to make sure they feed and regenerate only on *Melaleuca quinquenervia*. So far, three biological control agents have passed the screening tests and been approved for release on melaleuca in Florida. They are a weevil, a psyllid, and a bud gall fly. The weevil and psyllid are both already widely established throughout melaleuca infested areas of Florida. Experimental releases of the bud gall fly, the most recently introduced agent, are underway.

There are many benefits of the biological control program for melaleuca. Although initiating the program requires a consistent commitment of time and money for research, once the insects have been released and established they provide a highly cost-effective tool for suppressing melaleuca because they are free, self-sustaining and self-dispersing. The insects are able to survive and reproduce all year on melaleuca in Florida, allowing their populations to continually expand. Adults are winged and fly or otherwise disperse to colonize new stands. This is particularly important because many melaleuca infestations are in remote or environmentally sensitive areas where treatment may be difficult. In addition, many melaleuca infestations are on privately

owned property and go untreated because the owners have no incentive or lack the funding or expertise to do so. Biological control agents can spread to and help contain these remote and unmanaged infestations to keep them from proliferating.

The beneficial impacts of the melaleuca biological control program can already be observed, although it may take several years for them to reach their full potential. Additional agents may also be required to fully contain the spread of melaleuca. Research therefore continues on screening new biological control agents for introduction.

How Safe are Biological Control Agents?

The primary consideration in selecting biological control agents is host-specificity. Host-specificity means that agents will only feed and complete their development on the target plant. Only agents that are believed to have a narrow host range are brought into the US for further research, and then they undergo intensive screening in an approved biological control quarantine facility to make absolutely sure that the target plant is their only host. In quarantine, a long list of test plants, including species that are related to the target, endangered or threatened species, and economically important plants, are exposed to the candidate biological control agents in no-choice feeding conditions. This means that the proposed agents either feed on the test plant or die of starvation. Additional testing is conducted to make sure that adult females of the agents will lay their eggs, and the eggs will survive, only on the target plant.

In the eight years since the first biological control agents for melaleuca were released, a series of garden plots and field studies have been conducted to confirm that the insects' specificity for melaleuca as a host seen in the laboratory holds true in the field as well. Results from these studies show that the agents consistently select melaleuca over other species for egg laying and feeding. Adult biological control agents may rest temporarily on other plants, but neither oviposition nor sustained feeding (completion of development) on native species have been observed after four years of field assessments. Consistent with the results from quarantine testing, minor weevil feeding -- but not development -- does occur on the Australian bottle brush trees, *Melaleuca* (=*Callistemon*).

Impacts

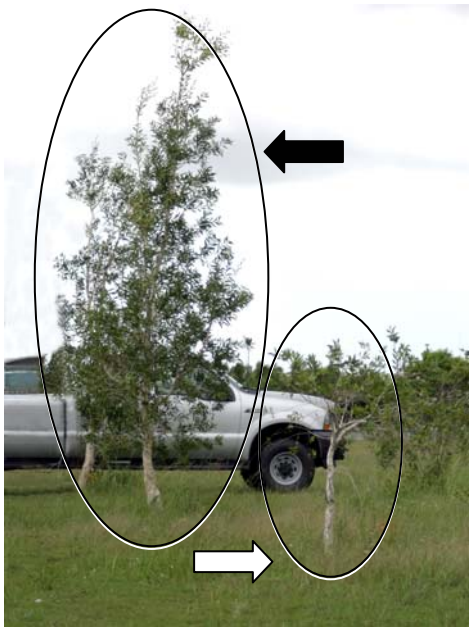
Feeding damage by melaleuca biological control agents can significantly stunt growth and reduce flowering. Both the weevil and the psyllid feed on tender new growth at branch tips, where new foliage and flowers are produced. Psyllids also feed on mature leaves, causing them to discolor and drop prematurely. The trees produce new foliage in response to defoliation, but new growth is quickly colonized by the biological control insects. Repeated cycles of development and defoliation deplete plant resources and reduce tree vigor, which may make the trees more susceptible to other stresses such as drought, freezing temperatures, mechanical damage, and herbicide.

Specifically, studies have shown that prolonged feeding by melaleuca biological control agents:

- significantly stunts growth of saplings
- delays initial reproduction (flowering) in young trees
- significantly reduces, by a factor of 36, the likelihood of flowering in mature trees
- reduces the number of flowers and seed capsules produced by as much as 80% in mature trees
- reduces biomass of re-growth on cut stumps by more than 55%
- causes as much as 65% mortality among small seedlings

Figure 30 and Figure 31 show the kind of impact the melaleuca weevil can have on melaleuca. The healthy branch on the left in Figure 31 has not been fed on by weevils. Feeding by weevil larvae has defoliated the branch on the right.

Figure 33 shows the impact that the melaleuca psyllid has on the flowering of melaleuca. Note the white fluffy flocculence, a sure sign of the presence of psyllids.



Two melaleuca trees in Figure 32 were planted at the same time. The tree on the left (black arrow) was protected from biological control agents. The biological control agents were free to attack the tree on the right (white arrow).

Figure 32. Stunted growth

Figure 30. Damage caused by melaleuca weevils

Figure 31. Defoliation caused by melaleuca weevils

Figure 33. Reduced flowering caused by melaleuca psyllids

Biological Control Agents of Melaleuca

As of this printing, there have been three biological control agents released in Florida, and more are on the way.

Melaleuca Weevils

Scientific name: *Oxyops vitiosa*

First released in April 1997, melaleuca weevils have been distributed to over 150 locations. Adult weevils may live longer than one year, and females may produce up to 1,000 eggs. Weevil eggs hatch after seven days and spend seven weeks as larvae. When the larvae are ready to pupate, they cease feeding, crawl or drop to the ground, and spend about four weeks underground in an earthen capsule. Due to this time spent in the soil, weevils do not fare well in permanently flooded habitats.

Eggs

The eggs of the melaleuca weevil are yellow, 1 mm long and resemble gel capsules (Figure 34). The female almost always covers the eggs in a secretion as soon as they are deposited to protect them from desiccation or predation. This secretion dries to form a hard protective casing, which is brown to black in color. When the eggs are present, they are usually associated with adult feeding damage.

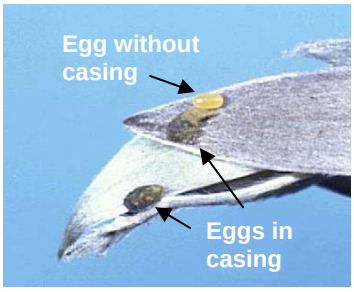


Figure 34. Melaleuca weevil eggs

Larvae

The larval stage has four instars, or growth phases. The appearance and size of the larvae vary depending upon their age. Neonates, or newly hatched larvae, are yellow and less than 1 mm long. In contrast, the mature larvae (Figure 35) are up to 14 mm in length, grayish in color and slug-like in appearance. Developing larvae are usually covered with a translucent yellow or orange oily secretion that turns black after fecal material is incorporated into it. This secretion is composed of plant oils ingested by larvae as they feed. The oily secretion mixed with fecal matter affords the larvae protection from fire ants and possibly other predators. Larvae are also often trailing a thin coil of fecal matter, giving the appearance of having a tail. The larvae consume all layers of the leaf except for the cuticle on the opposite side. The resulting paper-thin feeding trails in the leaves are a clear indication that melaleuca weevils are present.

Figure 35. Melaleuca weevil larva

Pupae

The pupal stage is not visible because it occurs beneath the soil surface. Larvae develop to the pupal stage inside an earthen capsule formed by the prepupae. The pupal capsule, which is made of soil and an oily secretion produced by the insect, is approximately 10 mm in diameter. The newly formed pupae are of the exarate type (i.e., the legs and wings are free and not glued to the body), and are yellowish in color but turn brown prior to emerging as adults.

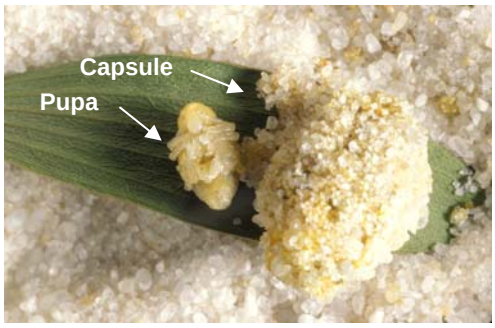


Figure 36. Melaleuca weevil pupae

Adults

Melaleuca weevils are small, gray and 6 to 9 mm in length. Males are usually smaller than females. The adults are somewhat cryptic in appearance, but are usually found on the leaves and stems of saplings or the new growth of older trees where they feed, mate and deposit their eggs. The presence of adults is usually indicated by the characteristic feeding damage that consists of holes or gouges chewed into the buds, leaves and stems. Occasionally, young shoot tips are nearly excised when stem feeding occurs on the tender new growth.

Actual Size

Figure 37. Melaleuca weevil adult

Melaleuca Psyllids

Scientific name: *Boreioglycaspis melaleucae*

First released in April 2002, the melaleuca psyllid (SILL-id) is difficult to see directly because of its small size (3 mm). However, its nymphs (immatures) are easy to detect from the waxy, cotton-like flocculence that they secrete onto melaleuca leaves and stems. This wax is harmless and washes off with rain. Psyllids complete their entire six-week life cycle on the melaleuca tree.

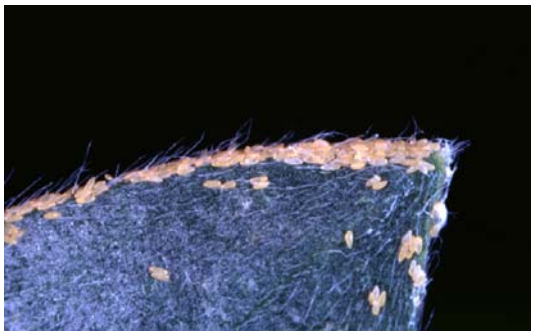


Figure 38. Melaleuca psyllid eggs

Eggs

Melaleuca psyllids lay their eggs on leaves and stems. The eggs hatch in about two

weeks. Eggs (Figure 38) are pale to bright yellow and are laid singly or in groups on leaves and stems of melaleuca. They are held onto the leaf by a narrow projection or pedicel inserted into the leaf.

Nymphs

Nymphs (Figure 39) take about three weeks to develop into adults and cause the majority of feeding damage. The psyllid nymph has five instars. Except for neonates (or newly hatched insects), the nymphs tend to be sedentary unless disturbed. First instars are pale yellow with no markings, but by the 5th instar they have gray to black markings on the body. Nymphs secrete conspicuous snow white waxy filaments from their abdomen while feeding. The filamentous wax loosely covers their bodies. Branches and leaves may become covered with the waxy filaments (Figure 40) creating a flocculence (wool-like tufts) indicating a heavy infestation. Rain will wash away the flocculence, but nymphs will soon secrete more. In addition, they produce copious amounts of honeydew held externally in balloon-like waxy membranes; nymphs discard honeydew filled spheres nearby. Adults also excrete waxy spheres of honeydew, but they flip them away from their immediate area.

Figure 39. Melaleuca psyllid nymph

Adults

Adults are small, about 3 mm long, and inconspicuous. Adult color ranges from pale yellow-orange to white with gray to black markings. The tips of the antennae are gray to black and the wings are transparent with yellow veins. The compound eyes are usually pale green with a distinctive dark spot within, but various shades of red have been observed in the laboratory; its three ocelli are bright orange, the dorsal two being the most obvious. Two prominent finger-shaped appendages or genae extend outward and slightly downward from beneath the eyes. When resting or feeding, the body is parallel to leaf or stem surfaces unlike, for example, the invasive Asian citrus psyllid, *Diaphorina citri*, that holds its body at a 45º angle.

Figure 40. Flocculence

Actual Size

Figure 41. Melaleuca psyllid adult

Males and females can be distinguished easily from one another by the shape of their abdomens and by the male genitalia. The abdomen of a male is shaped like an elongated isosceles triangle when viewed from above and terminates in distinctive claspers, easily apparent when viewed laterally. The abdomen of a female is more rectangular, gradually tapering to the tip; the pleural membranes usually are expanded, partially visible from above, bulging with eggs. Females generally are larger than males. Adults frequently drag their hind legs when walking, and jump or fly when disturbed.

Melaleuca Bud Gall Flies

Scientific name: *Fergusonina turneri*

The melaleuca bud gall fly is the third biological control agent for melaleuca. It is affectionately called "the Ferg," (taken from its scientific name).

The bud gall fly lays its eggs in melaleuca buds (Figure 42). Along with its eggs, the bud gall fly also deposits mutualistic nematodes that cause abnormal growths of plant tissue, called galls, to form on the melaleuca (Figure 43).

The more energy the plant diverts to gall creation, the less energy it has to produce flowers and seeds, thereby reducing the plant's reproductive ability. The bud gall fly larvae also feed on the galls, further exacerbating the plant's condition.

Actual Size

Figure 42. Melaleuca bud gall fly

Figure 43. Gall caused by the melaleuca bud gall fly

Rust Disease on Melaleuca

The weevil, psyllid and bud gall fly are natural enemies of melaleuca that were introduced, after years of careful study, for employment as biological control agents. Another natural enemy of melaleuca, the leaf-rust fungus, *Puccinia psidii*, of Brazilian origin, was not introduced intentionally but occurs and

spreads naturally in most melaleuca populations of Florida. Although not an official biological control agent, the rust vigorously attacks newly growing tips (Figure 44) of melaleuca trees of all ages. It causes stem defoliation and dieback of tips that would otherwise elongate and flower.

Figure 44. Rust disease on melaleuca

Rust disease epidemics on melaleuca coincide with its growing season (September-May), but low level disease continues to occur on new growth produced in response to various biotic and abiotic stresses. Thus, rust-spore production and disease level in melaleuca forests fluctuates with the amount of healthy branch-tips available on melaleuca trees and the associated microenvironment in the area. Overall, melaleuca rust contributes to reduced health, flowering, seed production, and seedling recruiting potential of melaleuca trees in Florida.

Acquiring Biological Control Agents

Although biological control agents are probably already at work on your melaleuca, you can supplement their numbers, thus increasing their effectiveness, by ordering them or collecting them yourself. At this point, only melaleuca weevils and psyllids are available for ordering or even found in the wild. The melaleuca bud gall fly is still in the process of establishing a viable population, and is currently rarely spotted in the wild.

Ordering Insects from the University of Florida

To order biological control insects from the University of Florida Institute for Food and Agricultural Sciences (IFAS), copy the form in Appendix B, fill out the form, include a check for the proper shipping and handling fee, then mail the form and check to the address on the form. The form is also available online at: http://kgioeli.ifas.ufl.edu/biocontrolorder.htm.

Collecting Insects for Redistribution

Where to collect

Melaleuca weevils and psyllids generally are found everywhere there are large quantities of melaleuca. An exception is any location that is flooded year-long. Weevils pupate in the soil and will not thrive in flooded areas. Heavy rains may diminish psyllid populations but they usually return to normal population levels within a couple of weeks.

For both insects, the best place to find them is on new growth, such as on younger trees (saplings), fresh re-growth after a tree has been cut down or

mowed, or at branch tips on more mature trees. Look for branches and leaves with signs of insect infestation, such as weevil feeding scars (see Figure 30) or white flocculence (see Figure 40) from the psyllids.

Figure 45. Container for collecting melaleuca weevils

When to collect

Melaleuca biological control insects are most prevalent from late fall through spring when melaleuca is producing new growth and heavy rains are infrequent. This is the best time to collect.

Collection equipment and techniques

Both the weevils and psyllids are flying insects. You will need a covered container to prevent them from escaping.

Weevils. Figure 45 shows a makeshift weevil collector made from a plastic container and a household funnel. The funnel was glued into a hole in the container cover using hot glue.

Figure 46. Weevil clutching a stem

It is easiest to collect adult weevils. However, they may be difficult to spot at first (Figure 46). They are the same color as the twigs and are often found near the ends of the twigs or at the joint where the twig meets a branch. You can pick them from the melaleuca with your fingers and drop them into a container. When disturbed, the weevils "play dead" and fall to the ground. Hold the container under the weevil as you reach for it to catch the weevil if it falls.

Psyllids. Scientists use a device called an aspirator (Figure 47) to collect adult psyllids. The device allows them to suck the psyllids into a vial for later redistribution. Aspirators are available from science equipment suppliers and are not expensive, often less than $10.

Figure 47. Aspirator for collecting melaleuca psyllids

Figure 48. Bucket to attract psyllids

Melaleuca psyllid adults are attracted to orange and yellow objects such as the bucket in Figure 48. An easy technique to collect psyllids it to shake infested branches over a similarly colored bucket, then aspirate the psyllids from the bucket.

Releasing Biological Control Agents

When releasing biological control agents you should pay particular attention to weather conditions. Overly hot and overly rainy conditions can destroy colonies of insects. Consideration must also be given to the season. Insects survive better in the late fall through spring when melaleuca produces new growth.

It might take four to six months to see evidence of the insects on your melaleuca. Because of unpredictable environmental conditions, there is no guarantee that they will actually establish. For evidence that the psyllid has established, look for the white, waxy material on the leaves and at branch tips. For evidence that the weevil has established, look for the slug-like larvae and their longitudinal feeding scars on tender new leaves.

General Tips

- Release the insects the same day you collect or receive them. Do not remove them from their container until you are ready to release them onto the melaleuca trees.

- Select 5 (or fewer) melaleuca trees. These trees should be in close proximity (within an area of 1/4 acre or less). If possible, select trees that have new growth on them (leaves near ends of branches are a lighter green than other leaves.)

Release Procedure for Melaleuca Weevils

Take weevils from the container and place them on young melaleuca leaves. If you are working with weevil larvae, be aware that their oily coating may stain clothes.

Release Procedure for Melaleuca Psyllids

If you have adult psyllids in a container, stand close to melaleuca trees when you open the container. Tap the opened container a few times to encourage the psyllids to fly away.

You may have melaleuca branches inoculated with psyllid nymphs. Remove these branches from the container and place them on melaleuca branches, on tender new growth if possible. If necessary, use tape or twist ties to secure these inoculated branches to the trees so that the leaves are touching and the nymphs may crawl over to the new leaves.

Integrated Pest Management (IPM)

What is IPM?

IPM, as defined under the USDA IPM Initiative, is "a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks". Often a goal of using such an approach is to use as few resources (labor, time, pesticides, fuel, etc.) as possible while still achieving effective pest control.

The foundation of a successful IPM program is prevention, detection, and suppression. A pest problem may be avoided or minimized from the beginning by reducing possible sources of infestation and the conditions that foster new infestations. Regular monitoring to detect and identify emerging infestations is essential for effective rapid responses with appropriate treatments. Monitoring may also help identify patterns of infestation that may serve as a basis for treatment decisions. When infestations do occur, management tactics are employed to suppress pest populations below an economically or environmentally damaging threshold. The details of an IPM program for a particular pest will of course depend on specific characteristics of that pest and of the site being treated, and on treatment tactics available.

IPM for Melaleuca

No single control tactic will be sufficient to manage melaleuca. Following the two-pronged approach recommended in the Melaleuca Management Plan, it requires tactics for removal of established trees combined with tactics to prevent reproduction and regeneration. Mechanical and chemical methods are the principle ways to kill or remove trees. In many cases, a combination of the two is most effective. Seed release and germination following any treatment of mature trees requires a second treatment, whether mechanical or herbicidal. Possible re-growth (coppicing) of treated trees may also require additional treatments. Often the cycle of treatment combinations must be repeated in order to suppress an infestation. In any case, continued monitoring of treated sites is required.

Although biological control will not remove mature stands, it can easily serve as the foundation of an integrated approach to melaleuca management. Long term feeding by the biological control agents can both suppress current populations and prevent the spread of new invasions. This can reduce the intensity of other management tactics needed and may even improve their efficacy.

In the remainder of this section you will find examples of how land managers could use damage caused by the insects to their advantage in an integrated

approach with other conventional control tactics. In all cases, biological control may help reduce frequency or intensity of treatments, possibly saving time, labor, and herbicide use. These resources may then be better applied to other, more urgent management needs. Regular monitoring, however, is still necessary to verify melaleuca containment and inform management decisions for specific situations.

Cut trees or mechanical removal. When melaleuca trees are felled by hand or with heavy machinery, re-growth of cut stumps or remaining root crowns is common. Stumps are usually treated with herbicide when first cut, but coppicing is still possible. Feeding by biological control agents on vegetative re-growth significantly reduces its height and biomass. In addition, it delays flowering and seed set by re-growth, which makes prompt re-treatment less critical to preventing spread. This allows follow-up treatments to be delayed and saves resources. And although it has not been proven yet, there are also some indications that trees subjected to biological control feeding for several years may not have enough reserves to re-sprout as vigorously when cut down, further reducing the urgency of follow-up treatment.

Figure 49. Comparison of healthy cut stump re-growth (left) and re-growth attacked by biological control agents (right)

Mowed pasture. A common practice in grazing pastures is to periodically mow coppicing melaleuca stumps to limit their growth. Studies show that if biological control agents are present, continual defoliation by the insects combined with the regular mowing regime can lead to more than 80% mortality of stumps.

Hack and squirt (frill and girdle). Massive seed release after a hack and squirt application can lead to a dense covering of seedlings that must be removed. The tender foliage of seedlings is highly attractive to biological control insects, and also highly susceptible to them. Seedlings exposed to the insects suffer more than 65% mortality (Figure 50). This can help reduce follow-up treatments or limit them to spot treatments. Prolonged feeding by the insects previous to a hack and squirt application may also make trees less vigorous and more susceptible to the application.

Foliar herbicide application. Another way that biological control fits into an integrated approach is by enhancing foliar herbicide applications. As trees become stressed and defoliated by insect feeding, they compensate by continually pushing new foliage, which uptakes herbicide more readily than mature leaves. Melaleuca's susceptibility to foliar application may also be increased because feeding scars left by biological control agents may allow better penetration of the herbicide. Additional research is needed to verify these observations, but it could mean aerial and other foliar herbicide applications may be done with lower rates or less frequently.

Figure 50. Seedling defoliated by biological control agents

Unmanaged areas. Feeding by melaleuca biological control insects reduces flowering and seed production, limiting the reproductive potential of melaleuca and making it less likely to spread into new areas. Removal of a mature stand of melaleuca may therefore be less of a priority for managers, particularly if there are other plant species present that pose a greater invasive risk and are not under any biological control (e.g., Old World climbing fern, Brazilian peppertree). If biological control is limiting seed production, melaleuca removal may then be delayed in favor of focusing resources on more urgent threats. In addition, biological control decreases canopy density in melaleuca stands over time. This makes melaleuca a weaker competitor for light, more light reaches the understory, and other vegetation is able to establish. The threat of melaleuca to native vegetation is therefore reduced and the urgency of melaleuca removal decreased. Again, this allows resources to be spent elsewhere.

Figure 51. Fire quickly wicks its way up the papery bark toward the canopy

Fire. Melaleuca is a fire adapted species. Leaf litter decomposes slowly, creating a heavy ground fuel load. The thick, spongy bark protects the cambium layer while the papery outer layers serve as a ladder to shuttle flames to the canopy (Figure 51). Volatile oils in the foliage fuel intense crown fires that kill other vegetation and produce thick, black smoke that can be a

nuisance to people (Figure 52). The stress from fire induces melaleuca seed release and leaves behind nutrient-rich ashen soil and a newly opened canopy, ideal conditions for melaleuca seed germination and seedling growth. Epicormic buds on surviving trees quickly sprout and flowers may occur within weeks of a fire. This process can quickly increase melaleuca's spread and density.

Figure 52. The oils in melaleuca leaves promote hot catastrophic fires

Employing fire to manage melaleuca requires careful consideration and timing. Because of the expected seed release from mature melaleuca trees following a fire, burning of mature stands should be timed either at the beginning of the wet season when soil is moist enough to induce germination and seasonal flooding will soon submerge and kill seedlings, or at the end of the wet season when soil moisture is still high enough for germination but drought will soon kill seedlings. The unpredictability of seasonal inundations and droughts, however, may make follow-up treatments of seedlings necessary.

Another method of incorporating fire into melaleuca management is to kill mature trees using other methods, thereby inducing seed release, and follow up with controlled ground burns to kill newly emerged seedlings. However, melaleuca trees treated with herbicide with apparent success have been observed to re-sprout following a fire, as if the herbicide were never applied. Therefore, to ensure maximum efficacy of herbicide treatments, it is recommended that you wait at least one year after herbicide application before conducting a follow-up burn.

Interaction between the biological control agents and fire is not yet clear. There are some indications that melaleuca trees that have been exposed to the insects for multiple seasons may be so stressed by feeding damage that they are less likely to survive an intense fire. And insects that re-colonize melaleuca after a fire may help suppress new foliage and flowers on surviving trees and increase mortality of emerging seedlings.

Despite these possible strategies, fire is not an ideal management tool for melaleuca. It can be particularly risky in many upland habitats where melaleuca may be intermixed with desirable tree species such as pines or cypress. The risk exists because mature melaleuca trees will survive the fire while their papery bark and oil-rich leaves increase the fire's intensity to a level deadly to the other trees in the area.

TAME Melaleuca - The Next Step: Demonstrating Integration

With the introduction of biological control for melaleuca and recent improvements in herbicide and mechanical tactics, a mechanism was needed to inform people about these latest developments. In 2001, the US Department of Agriculture Agricultural Research Service (USDA ARS) funded a five year demonstration and research project entitled The Area-wide Management and Evaluation of Melaleuca, or TAME Melaleuca. The project is a partnership between USDA-ARS, the South Florida Water Management District and the University of Florida's Institute of Food and Agriculture Sciences, with several other organizations and individuals contributing as well (see page iii for a list of cooperating agencies).

The principal goal of the TAME Melaleuca project is to demonstrate integrated melaleuca management based on the use of biological control but including all tactics. By demonstrating integration of biological control, the project hopes to also promote its use throughout melaleuca infested areas of Florida. The idea is that if biological controls are widespread ("area wide"), their impacts on melaleuca reproduction and growth would help contain infestations and suppress new ones, thereby reducing reliance on chemical and mechanical treatments. In areas where melaleuca is present at an unacceptable level, mechanical or chemical treatments would also be used. In these cases, the suppressive nature of the biological control agents on tree vigor and reproduction could increase treatment efficacy and may reduce the need for repeated treatments.

Figure 53. Secretary of the Interior Gale Norton releasing melaleuca psyllids

This approach will only be successful if melaleuca biological control agents are as widespread as melaleuca, and their populations are allowed to proliferate. Resource managers must also be aware of damage caused by the insects and how it can improve their management efforts.

TAME Melaleuca has nine demonstration sites throughout south Florida to show people the most current and effective melaleuca management strategies, including use of biological control. Project demonstration sites range in size from 7 acres to nearly 100 acres and represent a variety of ownerships, habitats and melaleuca infestation levels. Biological, chemical and mechanical controls described in this manual were applied alone and in different combinations at each site. A series of educational workshops and tours held at the sites offer resource managers, applicators, scientists, and other end users a chance to see integration of biological control in action.

Figure 54. TAME Melaleuca Project demonstration site

In addition to demonstration activities, TAME Melaleuca is also sponsoring research on various aspects of melaleuca biology, invasion and management. Socio-economic surveys are being used to identify factors that influence melaleuca management decisions. Assessments are also being conducted on the economics of available treatment options and on the regional economic impacts of melaleuca invasion. TAME project cooperators are documenting the extent of melaleuca's distribution in Florida and other regions outside of its native range. Additional research continues to look at the biology of biological control agents and their performance in the field.

Figure 55. Researchers collecting data at one of the TAME Melaleuca sites

Details on all TAME Melaleuca activities can be found on the project web site (http://tame.ifas.ufl.edu), including demonstration site descriptions and images.

Figure 56. Demonstration workshop being held in Lee County

The site also serves as a clearing house for current and historical information about melaleuca and its management. Informational brochures, extension bulletins, scientific reports and other resource documents are also available on the site for reading and downloading.

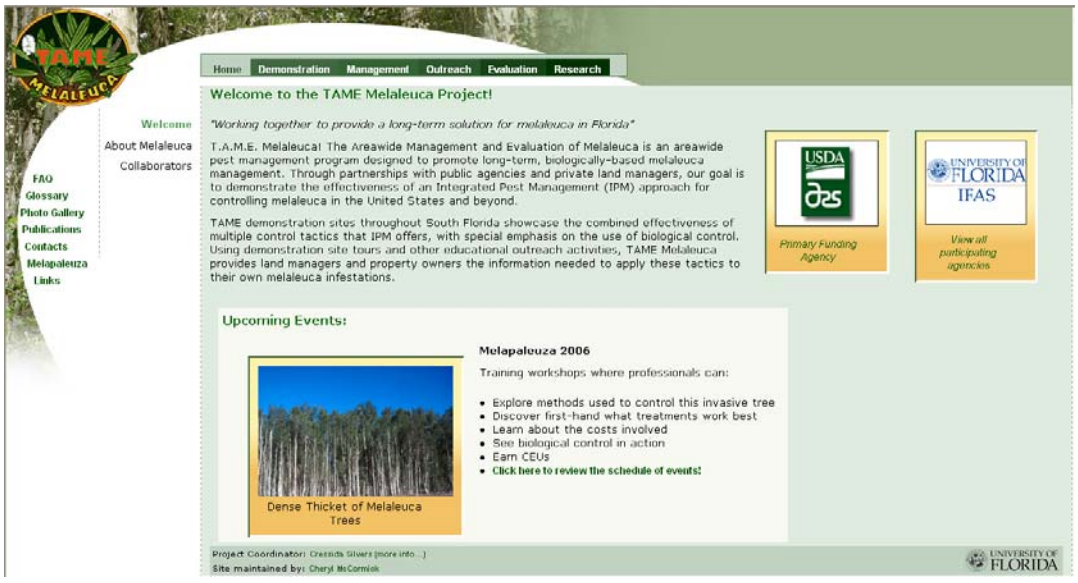


Figure 57. TAME Melaleuca website http://tame.ifas.ufl.edu

Melaleuca and the Law

Various federal, state, and local laws apply to melaleuca. The federal government (USDA) includes melaleuca on the Federal Noxious Weeds List, prohibiting its importation and interstate transport without a special permit. Two state agencies, the Florida Department of Environmental Protection (FDEP) and the Florida Department of Agriculture and Consumer Services (FDACS), regulate melaleuca as an aquatic and terrestrial weed, respectively, making it unlawful to possess, collect, release, transport, cultivate, import or introduce the tree without a special permit.

The Law - Simply Put

It is illegal to possess, collect, transport, cultivate, or sell *Melaleuca quinquenervia* without a permit. This includes seeds or any other plant parts.

Melaleuca is similarly regulated in many counties and municipalities through local invasive species ordinances. In addition, local ordinances often include building code statutes that require newly developed properties be cleared of melaleuca (and other invasive exotic plants) and maintained free of invasive plants for a designated time or indefinitely.

Many localities require permits for tree removal in an effort to preserve urban canopies. Most, however, have exemptions for melaleuca and other invasive exotics, allowing their removal without prior approval. A free permit may still be required to make sure native or other desirable vegetation is not removed by mistake. Also, if the tree removal process involves heavy equipment (other than chainsaws) or is taking place in environmentally sensitive areas or wetlands, a permit may be required.

You should always check with your county and local authorities before initiating any of the control options defined in this document.

Glossary

Adjuvant – an ingredient that modifies or aids the principle ingredient.

Adventitious - describes roots or shoots or other parts that grow in an uncharacteristic place on a plant (such as roots growing from leaves).

Apical bud – a bud located at the tip of a stem or branch.

Axillary bud - a bud located in the axil of a plant, at the junction of a branch and leaf stem.

Biomass - the total mass of living tissue within a given unit.

Cambium - the layer of living tissue between the bark and wood in woody plants, from which new wood and bark develops.

Canopy – the uppermost layer in a forest formed by the crowns of trees.

Capsule - a case, pod, or fruit, containing seeds, spores, or carpels; it usually bursts when ripe.

Coppice – shoots produced from older stumps rather than from seed.

Defoliation – the loss of leaves.

Desiccation – the process of drying out.

Epicormic bud – dormant buds formed in the axils of leaves on the young shoot that fail to develop but grow enough to stay at or just below the surface of the bark. They will sprout to form new branches if the crown of the tree is damaged. They may also be adventitious, sometimes forming on callus tissue.

Essential oils – oils in plants that give them their odor and other characteristics.

Evapotranspiration – combination of water loss through evaporation from the soil and transpiration from the plant

Foliar – of or relating to leaves or a leaf.

Hack and squirt – a technique for killing a tree where a groove is cut through to the cambium layer all the way around the tree and herbicide then applied to the cut.

Herbaceous – non-woody plants or plant parts.

Instar – the stages of life of insects between molts.

Invasive plant – a species that is alien to a specific habitat and has successfully colonized the local plant community, displacing indigenous species in the process. Invasive species can successfully establish in undisturbed habitats (as opposed to ruderal species) and become dominant.

This often results in the replacement of diverse plant communities with monocultures of the invading species.

Inflorescence - a flower or putting forth blossoms; the mode of development and arrangement of flowers on an axis; a flowering branch.

Photosynthesis – the process of using light as the energy source to synthesize carbon dioxide and water into carbohydrates.

Predation – capturing prey to maintain life.

Ruderal – growing in poor land such as rubbish or waste.

Surfactant – a substance used to reduce the surface tension of liquid in which it is dissolved.

Translocate – the transfer from one location to another, specifically, the movement of herbicide throughout the vascular system of a plant.

Transpiration – the emission of water vapor from leaves and other parts of plants.

Vascular tissue – conductive tissue in plants.

Additional Resources

Web Sites

Agricultural Research Service www.ars.usda.gov

Atlas of Florida Vascular Plants, University of South Florida
www.plantatlas.usf.edu

Center for Aquatic and Invasive Plants, University of Florida
http://plants.ifas.ufl.edu

Federal Noxious Weed Program www.aphis.usda.gov/ppq/weeds

Florida Department of Agriculture, Department of Plant Industry
www.doacs.state.fl.us/pi/

Florida Department of Environmental Protection,
Bureau of Invasive Plant Management www.dep.state.fl.us/lands/invaspec

Florida Exotic Pest Plant Council www.fleppc.org

Invasive Plant Research Laboratory
www.ars.usda.gov/saa/iprl

The National Agricultural Library's Invasive Species website
www.invasivespeciesinfo.gov

South Florida Water Management District
www.sfwmd.gov

Southwest Florida Water Management District
www.swfwmd.state.fl.us

TAME Melaleuca Project http://tame.ifas.ufl.edu

The Nature Conservancy Invasive Species Initiative
http://nature.org/initiatives/invasivespecies/

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For a more extensive list of references, visit the TAME Melaleuca website at http://tame.ifas.ufl.edu

Appendix A - Frequently Asked Questions

Q. Do melaleuca trees use up more water than other trees?

A. A single melaleuca tree does not necessarily use up, or transpire, any more water than a single tree of any other species. But a melaleuca forest may transpire more water than the sawgrass prairie it most likely replaced. In addition, the melaleuca canopy partially intercepts rainfall, preventing it from reaching the ground and moistening the soil. Finally, melaleuca leaf litter falling to the ground raises the soil level and further contributes to drying of the invaded site.

Q. Does melaleuca cause allergies?

A. Melaleuca flowers throughout the year and many people have positive allergic reactions to its pollen in clinical allergy tests. But melaleuca is pollinated by bees, not wind, and its pollen is not readily airborne. Skin exposure to oils in melaleuca bark or leaves may result in contact dermatitis.

Q. Will melaleuca be eradicated?

A. Eradication is usually only feasible when a pest has been detected early in the invasion process and is present in well-defined, localized areas where complete elimination is possible. That kind of opportunity is rare. Melaleuca has been here too long and is too widespread to eradicate. Instead the goal is to limit its invasive growth and spread so that it no longer dominates habitats, but is instead just another tree in the landscape.

Q. Is it legal to have melaleuca growing on my property?

A. Technically it is illegal, according to Florida Statutes 369.25 and 369.251 which state "no person shall import, transport, non-nursery cultivate, collect, sell, or possess any noxious aquatic plant" including melaleuca, and "a person may not sell, transport, collect, cultivate, or possess any plant, including any part or seed, of the species *Melaleuca quinquenervia*". However, while trees that have been in place for over a decade are not of immediate concern under the Florida Prohibited Plant Rules, state officials strongly encourage the voluntary removal of such trees. They serve as sources of constant re-infestation of nearby natural areas by windblown seed. Furthermore, melaleuca is regulated by the State of Florida and the federal government as a noxious weed. Melaleuca trees may also be locally regulated, as they are in Palm Beach and Lee Counties.

Q. Is this the same melaleuca used to make herbal shampoo and tea tree oil?

A. No, it is a different species. Melaleuca found in Florida is *Melaleuca quinquenervia*, while the "tea tree" species is *Melaleuca alterniflora*.

Q. Is melaleuca mulch safe to use? Where can I get it?

A. Yes, commercial, bagged melaleuca mulch has been composted thoroughly to kill viable seeds. It makes good mulch because it does not float, it's long lasting, and it is not attractive to termites. It is also a good alternative to harvesting native cypress trees. As far as we know, Florimulch is the only commercially available melaleuca mulch. Sometimes it can be found in home and garden stores, or you can try contacting the producer directly. You'll find a link to their website on the TAME Melaleuca website Links page (this is not an endorsement, just acknowledgement that this is currently the only source). Companies that mulch trees, such as tree-trimming companies, might be able to provide bulk melaleuca mulch, although the fineness of the mulch may vary. And be careful, it could contain viable seeds if it has not been properly composted.

Q. Do I need a permit to cut down my melaleuca tree?

A. Most municipalities that require permits for tree removal have some sort of exemption for melaleuca and other invasive plants. A permit may still be required but the fee may be waived, or a permit may not be necessary at all. Before removing any tree, however, check with your city or county environmental resources department or equivalent to be sure you are in compliance with permitting requirements.

Q. How do I safely dispose of the debris so it won't spread melaleuca?

A. In most cases, melaleuca and other invasive plant debris can be included in curb-side waste pick-up, bulk waste pick-up, or green yard waste pick-up, if your city provides that service. Contact your local waste management department to find out your options. Any seeds on the tree will be released within days of killing the tree; try to contain debris and seeds in a small area to limit seed dispersal and limit the area where follow-up treatments of new seedlings may be needed. Keep cut branches, trunks and uprooted seedlings well out of reach of water or wet soil. Debris can be mulched but should then be composted for at least three months to kill seeds. Melaleuca wood can also be burned.

Q. Where can I find a professional to take out my trees?

A. A list of certified, insured arborists in your area can be obtained from the Florida chapter of the International Society of Arboriculturalists, the Florida Division of Forestry, the Florida Department of Environmental Protection, or your county cooperative extension office.

Q. Where do the biological control insects come from?

A. Melaleuca biological control agents released in Florida were collected from the tree's native range in Australia. In Australia, there are hundreds of insects and diseases that attack melaleuca and keep it in check.

Q. Will they harm me/my family/my pets?

A. No, melaleuca biological control agents do not attack or infest people or animals. Their mouths and digestive systems are specifically adapted for feeding only on melaleuca.

Q. What is that white fluffy stuff on my trees?

A. The melaleuca psyllid exudes a waxy filament from its body as it feeds. Officially called flocculence, this waxy material is bright white, like cotton. It blows away easily and dissolves when you touch it. Throughout most of the year it is not too noticeable, but it can build up during dry spells. It is harmless and washes away easily with rain or with a hose.

Q. When I brush against a melaleuca tree I sometimes get yellow stains on my clothes and skin. Why?

A. Immature melaleuca weevils, or larvae, are small and slug-like. They exude an orange-yellow slime that coats their bodies. It is made of essential oils from the melaleuca leaves they eat and it helps protect them from predators like the red imported fire ant. Unfortunately, the slime stains cloth and skin a bright yellow. Rubbing alcohol will remove it from skin. For suggestions on removing it from clothing, see the information sheet "Melaleuca snout weevil larvae secretion removal"

Q. How do I know if biological controls are feeding on melaleuca trees?

A. The melaleuca psyllid pierces leaves with its straw-like mouthparts and sucks up plant sap, leaving no noticeable feeding scars. But the waxy, white, cotton-like flocculence produced by immature psyllids (or nymphs) as they feed provides an obvious sign of their presence (see Page 28). Look for flocculence on expanding leaves at branch tips and on either side of more mature leaves. Besides having the tell-tale white flocculence, leaves that are fed on by psyllids often become discolored, turning yellow then red before falling off.

The weevil, on the other hand, is a leaf chewer and produces obvious feeding scars. The majority of damage is caused by weevil larvae. The larvae feed on tender new leaves, chewing through the surface to the cuticle layer on the opposite side creating paper-thin feeding trails on the leaves. Damaged leaves curl up and turn brown. Adult weevils will chew holes or gouges in leaves, buds, and tender stems (see page 25).

Q. Will the insects kill the melaleuca?

A. The biological control agents were carefully selected to feed on melaleuca in such a way that doesn't kill the trees, but does slow down growth and seed production so the trees don't spread any further. Feeding damage may kill seedlings and smaller trees over time, but care was taken to select agents that would not kill mature trees.

There is, however, another insect feeding on melaleuca in some areas, notably Broward and Palm Beach Counties. This insect is an exotic invasive pest like melaleuca, and is thought to have been accidentally introduced on imported ornamental plants. It is the lobate lac scale and it feeds on hundreds of plant species, including melaleuca, with often deadly effect. It is an inconspicuous brown, bow-tie shaped bump on twigs and branches. Like many scales it secretes honeydew which serves as food for black sooty mold. Signs of lobate lac scale infestation include leaf drop, branch dieback, and black sooty mold on lower leaves, branches and understory vegetation.

Q. Will the melaleuca biological control insects eat other plants?

A. No. The primary consideration in selecting biological control agents is host-specificity. Host-specificity means that agents will only feed and complete their development on the target plant. Only agents that are believed to have a narrow host range are brought into the United States, and then they undergo intensive screening in an approved biological control quarantine facility to make absolutely sure the target plant is their only host. In quarantine, a long list of test plants, including species related to the target, endangered or threatened species, and economically important plants, are exposed to the candidate biological control agents in no-choice feeding conditions, meaning the proposed agents either feed on the test plant or die of starvation. Additional testing is conducted to make sure adult females of the agents will only lay their eggs on the target plant.

Q. How can I get biological control agents for melaleuca?

A. The melaleuca weevil and psyllid are already widely distributed and because the adults fly, they disperse on their own. So one or both agents are most likely already present on your melaleuca trees. If you would like to enhance their populations by releasing more, the St. Lucie County Cooperative Extension Office will ship them to you. An order form and instructions can be found in Appendix B - Order Form for Biological Control Agents and at http://kgioeli.ifas.ufl.edu/biocontrolorder.htm.

Appendix B - Order Form for Biological Control Agents

To order biological control insects from the Institute for Food and Agricultural Sciences, copy the form on the next page, fill out the form, include a check for the proper shipping and handling fee, then mail the form and check to the address on the form. The form is also available online at: http://tame.ifas.ufl.edu/html/faq.php.

MELALEUCA BIOLOGICAL CONTROL AGENT ORDER FORM

Gioeli will only ship to Central and South Florida counties where Melaleuca are found.

Name _____

County _____

Street Address _____

(We are unable to ship to P.O. Boxes)

City _____ State _____ Zip _____

Phone Number (_____) _____ E-mail _____

Release location:

Tell us how many orders you are requesting and calculate the shipping and handling fees:

# of orders		S&H
_____	x $20 =	_____

Total S&H Fees: _____

*The melaleuca biological control agents you receive will depend on seasonal availability. Psyllids are typically available year-round while weevils tend to be available seasonally. One order should be adequate to inoculate a ¼ acre site. Evidence of the establishment of your agents should be noticeable in approximately 6 months after the initial inoculation. Once the agents have established a viable population at the inoculation site, they should be able to spread to adjoining sites on their own. These agents are designed to be part of an integrated pest management program and should offer partial control of your melaleuca.

To harvest and transport your own biological control agents from the St. Lucie Co. Cooperative Extension office's melaleuca biological control agent honeypot, please complete this order form and fax or mail it to Ken Gioeli. Ken will contact you to set up an appointment to teach you to harvest the agent. There is no charge for this service if clients harvest and transport their own agents.

To receive your shipment via FedEx, please send your completed order form, along with a check for shipping and handling fees made payable to the "St. Lucie County 4-H Foundation" to

Ken Gioeli
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(772) 462-1660
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ktgioeli@ifas.ufl.edu

Form Revised April 2004

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