

# BIOLOGICAL CONTROL OF TROPICAL SODA APPLE



**A manual for the implementation of biological control as a  
tropical soda apple management tool**

*Prepared by Rodrigo Diaz, William A. Overholt,  
Ken Gioeli, Brent Sellers, and Julio Meda*



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**M**ost ranchers and natural area land managers in Florida are probably quite familiar with the thick mats and prickly appearance of tropical soda apple (TSA). It's no wonder this nasty weed has been called the "Plant from Hell." Tropical soda apple is native to South America, and was first seen in Florida in 1988 in Glades County. In addition to Florida, the plant has been reported in Georgia, Alabama, South Carolina, North Carolina, Tennessee and Texas. The invasion of TSA into the southeastern USA has resulted in negative environmental and economic impacts. Habitats invaded by TSA are less productive, wildlife corridors are blocked and species diversity is

reduced. Cattle ranchers lose an estimated \$6.5 million to \$16 million annually due to the cost of chemical and mechanical control of TSA.



**The success of TSA is facilitated by the spread of seeds by cattle.**

In addition to its impact on the cattle industry, TSA serves as a reservoir for several viruses and insect pests of cultivated crops.

TSA invasion is a major problem for ranchers due to the loss of pasture production and subsequent lower stocking rates. TSA is a perennial shrub, approximately 2-4 feet tall, and covered with prick-

## Meet Tropical Soda Apple (TSA)



These photographs show some of the features of tropical soda apple (TSA). Above left: TSA plant. Above middle: TSA flower. Facing page (above left): TSA fruits.

les and tiny hairs that contain a sticky substance. TSA fruits are about 1 inch in diameter, green with a watermelon color pattern when immature, and turning yellow when ripe.

Cattle and wild mammals feed on TSA fruits, thus, facilitating the spread of seeds across the landscape. The ability of TSA to grow well in shaded hammocks, as well as in open pastures, demonstrates the adaptability of this weed. The presence of TSA is most noticeable during the summer and fall when plants are actively growing due to high temperatures and adequate moisture.

Freezing winter temperatures kill TSA above the ground, but roots often survive and quickly produce new shoots. Winter surveys conducted in Florida demonstrated that TSA growing in open areas are more susceptible to freeze compared to plants growing in protected hammocks or pinelands.



**Manure with TSA plants**



*Originally introduced into Florida in the 1980's, tropical soda apple is a major problem in pasture and conservation areas in Florida.*

## **The purpose of this manual**

This manual provides the knowledge necessary for the successful application of biological control of tropical soda apple. The information provided includes the recognition and impact of the TSA leaf feeding beetle.

## **Biological control**

Biological control is an environmentally friendly and cost effective management method which aims to reduce an exotic weed population by using natural enemies, such as pathogens and insect herbivores, from the plant's native range. Once an agent is established at a site, populations are self-perpetuating and spread with little human intervention.

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## **The TSA leaf feeding beetle**

Due to the importance of TSA as an invasive weed, a search for biological control agents was initiated in South America in 1994. One agent identified and later introduced from Paraguay and northern Argentina was the TSA leaf feeding beetle, *Gratiana boliviana*.

Many different insect species typically feed on a plant in the plant's native range, some of which are generalists (feeding on many different plants), while others are specialists and feed only on one or a few plant species. Insects used for biological control are specialists which feed and maintain viable populations only on the target weed. Prior to their release, biological control agents undergo extensive host range testing to make sure that they will only feed on the target weed. In the case of the TSA leaf feeding beetle, scientists from the University of Florida/Institute of Food and Agricultural Sciences and the U.S. Department of Agriculture evaluated beetle survival, development and egg laying preference on 123 different plant species, including several close relatives of tropical soda apple, as well as many important crops. Beetles laid eggs and survived only on TSA. Thus, scientists were able to demonstrate that this beetle was a specialist on TSA.

After several laboratory and field experiments to determine the safety of the beetle, scientists submitted their data to federal and state agencies for review. A permit was approved in early 2003, and the beetle was released in Polk County, Fla. in May of the same year. Field monitoring in Florida has confirmed that the only plant attacked by the TSA leaf feeding beetle is tropical soda apple.



## Beetle biology

The beetle has four developmental stages (egg, larva, pupa, adult). **Eggs** are brown and enclosed in a membrane envelope, **larvae** are spiny and pale green, **pupae** are spiny, flattened and immobile, and **adults** are about ¼” long and nearly as wide, and a deep green color. Adults and larvae usually feed on the upper side of TSA leaves, while pupae and eggs can be found on the underside of leaves. The life cycle of the beetle begins when a female lays an egg. Eggs hatch in 5-6 days, larval development takes about 16-18 days, and the pupal stage lasts 6-7 days. Therefore, from egg to adult the beetle takes about 29-31 days at 77°F. Like all insects, development occurs faster when it's warm, and slower when it is cool.

The beetles actively feed and reproduce in the field from around March/April until October/November, which is probably sufficient time to complete about 7-8 generations. However, for 4-5 months during the winter, the beetles enter an adult resting state called “diapause.” During diapause, the beetles feed very little, and do not reproduce. They are difficult to find at this time of year, as they hide in leaf litter beneath plants.

## Damage/impact to TSA

Larvae and adults of the beetles feed on TSA leaves, with a preference for younger leaves near the tops of plants. The leaf feeding damage can be seen from April to November and is recognized by a characteristic “shotgun” hole pattern on leaves. This damage debilitates TSA and creates wounds that may facilitate attack by plant diseases. The cumulative stress produced by the beetles and diseases reduces plant size and fruit production. Once TSA becomes less competitive, pasture grasses and native vegetation recover.



Studies conducted by scientists at the University of Florida have demonstrated that the TSA leaf feeding beetle can reduce the density of TSA in as little as one year from the time of release, although in some cases it may take longer.

The TSA leaf feeding beetle will not completely eliminate the weed from an infested area. Once the density of TSA is reduced, the beetle population will decrease due to a lack of food. Eventually, TSA and beetles will reach an equilibrium where the density of beetles regulates the density of plants, and the density of plants regulates the number of beetles.

## Beetle Lifecycle



Adult beetles are brown from November to March and remain mostly in the leaf litter. Once the days become longer and warmer, adults turn green and move from the leaf litter to TSA leaves.



## Current beetle distribution

Some biological control agents spread very rapidly to colonize new areas, whereas others disperse more slowly. The TSA leaf feeding beetle spreads fairly slowly. Research suggests that the beetle will spread from release sites at a rate of about 2.5 miles per year. Thus, in order to speed up effective biological control of TSA, the beetle should be released at many different sites. Eventually, the beetle will fill in gaps between release sites and occupy all areas infested with TSA.



Eggs are found from March through October.  
Larvae and pupae are common from April to November.

## What do we want to accomplish?

We would like to inform ranchers and land managers about biological control of tropical soda apple, including how to obtain beetles, how to select sites for release, how to release the beetles, and how to integrate biological control with other management tactics. The biological control program depends on the successful establishment of beetle populations in an area. Once this is accomplished, the number of beetles will increase over time reducing TSA's ability to compete with other plants.

## How to get beetles

It is very likely that ranchers with TSA infestations in central and south Florida already have beetles on their property. During the early summer months, they should closely inspect TSA plants and look for the characteristic "shotgun" hole feeding pattern caused by the beetle. If evidence of feeding is observed, then closer inspection will reveal the presence of the beetles. When no beetles or damage are evident, land managers may be able to obtain beetles from established populations on neighboring properties. They can also contact the Florida Department of Agriculture, Division of Plant Industry, either directly or through a local extension agent.

## Where to release

Selection of good locations for initial release of beetles will increase the chances of establishment. Here are some important factors to consider when releasing beetles.

# Beetle Recognition



Egg



Larva



Pupa



= 1/8 inch



= 1/4 inch



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The TSA leaf feeding beetle produces a characteristic “shotgun” hole feeding pattern on leaves.

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**Green Adult**  
(Reproductively Active)



**Brown Adult**  
(Diapause State)

**TSA management.** Release beetles where TSA infestations will be undisturbed by management practices such as mowing or herbicide application. This will ensure a reliable source of food for the beetles. Hammock areas, where access by mowing and spraying equipment is difficult, are ideal release sites.

**Soil moisture.** Avoid releasing beetles in low areas that may be prone to seasonal flooding. TSA does not tolerate extended periods of flooding; therefore if beetles are released in such an area, and it does flood, many of the beetles will die along with the plants.

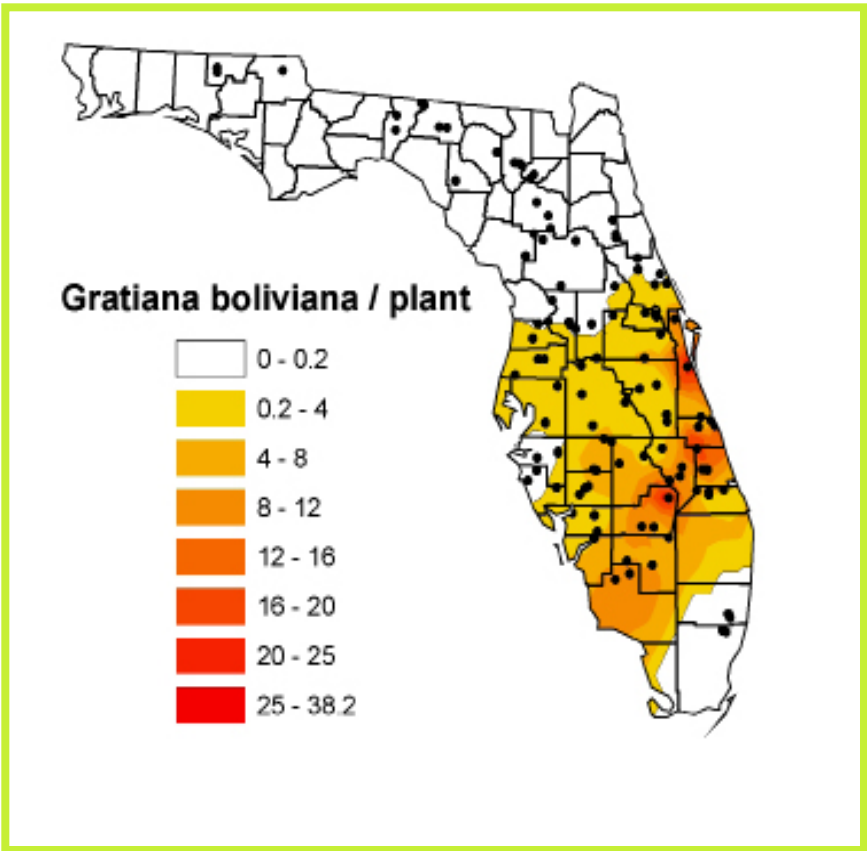
**TSA density.** The TSA infestation on your property may vary from a few isolated plants to large thick mats of several acres. When possible, release beetles in the middle of large, dense patches. This will ensure that the beetles you release, and their offspring, have plenty of food to develop into a large, healthy population.

## Beetle Distribution

A survey conducted in the fall of 2008 revealed that the TSA leaf feeding beetle had spread from release sites to surrounding infestations. After five years of releases, the beetle can be found in about 70% of pastures in central and south Florida. The image to the right shows the density of beetles per plant at different locations in Florida and areas where the beetle was absent. Releases during 2009 and 2010 will target northern areas in Florida.

**TSA plant quality.** Leaf quality is important for beetle nutrition. Concentrate releases on plants with deep green foliage and vigorous growth. This condition can be found in areas with cattle manure and rich soil conditions.

**Open vs. shade.** Florida rangelands are typically a mixture of open pastures and shaded habitats. TSA thrives during the summer under both conditions. However, winter freezes may kill plants in the open, while having only a minor effect on plants in more protected areas. To provide a reliable food source for a longer period, we recommend releasing beetles in shaded sites. Moreover, TSA management with mowing or herbicides is difficult in hammocks, so they are ideal locations for the release of beetles. Once the beetle population increases in the hammocks, they will naturally colonize TSA plants in the open.



## Beetle release

Now that you have selected suitable release sites on your property, the next step is to decide when and how many beetles to release.

**When?** You can release adult beetles any time from April to October, but earlier in the season is better. By releasing in the spring, beetles will have several months to reproduce and establish large populations before they diapause (enter a resting state) in the fall.

**How many?** We recommend an inoculative release of 200-400 beetles in an infested area, which could be several acres in size. Release beetles near the center of the infestation, by liberating 10-20 adults per plant, on 10-20 plants. The plants should be fairly close together, separated by 10 feet or less. Do not release only one beetle on a plant, as male and female adults need to be able to find each other to mate and reproduce. The beetle population will rapidly increase and spread from the plants on which they were released to neighboring plants.

**Documenting the release.** Watching the reduction of TSA density over the years due the beetle damage and diseases is a rewarding experience! If you have extra time and interest, mark the locations for future monitoring. Take pictures with visual reference (large trees, a fence) at the release site once or twice a year during the summer or fall. Do not





<b>Beetle releases</b>	
<b>Look for/ Do:</b>	<b>Avoid/ Don't:</b>
Healthy, deep green, vigorous TSA	Weak, yellowish TSA
Large patches	Small patches
Less disturbed locations	Highly disturbed location
Early in the growing season	Winter releases
More beetles per plant	Single beetles per plant

expect to see a reduction in the TSA population overnight, but over time, you will witness a significant reduction in the density.

### **Monitoring and beetle harvest**

The release of beetles is only the beginning of the biological control process. Monitoring the presence of beetles at a site is important because you can confirm their establishment, document damage to TSA, and estimate if beetles can be moved to new locations. The simple way to confirm that beetles have established at a site is to find beetles in the spring after their release during the previous spring or summer. Larval and adult activity is easily recognized by the “shotgun” damage to the leaves.

One year after the release, some sites experience beetle outbreaks (>20 adults/plant) during the summer and early fall. Ranchers could facilitate the dispersal of the beetle by harvesting from these locations and moving beetles to new sites. There are two ways to collect adult beetles from this thorny weed: with and without pain. You can collect adults by hand since they spend most of the time feeding and mating on the leaves. You can also wear gloves and use hand clippers to cut the leaves with adult beetles. Beetles with or without TSA plant material can be transported to new locations in any type of plastic container or jar with holes to allow air exchange. A paper towel or tissue in the container will absorb excess moisture. Keep the container out of direct sunlight. If beetles will be held for more than about one hour before release, they should be placed in a cooler to avoid over-heating. Release beetles the same day as they were collected, if at all possible.

# Before and After

Pictures are worth a thousand words. These before and after pictures on pages 13-18 show the levels of reduction in TSA density due to the beetles at a number of locations in Florida.



July 2006

St. Lucie County pre-release

## Testimonial

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Rancher Bobby Teague from St. Lucie County has been fighting RTSA in his pasture for several years. “TSA patches covered a large extension along the ranch driveways, open pastures and hammocks in the ranch,” Mr. Teague said. In the summer of 2007, UF/IFAS researchers released 200 beetles on Mr. Teague’s ranch. Since then, Mr. Teague has witnessed a reduction in TSA density.

“Certainly those beetles are munching on the soda apple,” Mr. Teague said. “I have seen the damage and the reduction in weed cover. Today, the soda apple is still in the property but the beetles are taking good care of it.”

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St. Lucie County, one year after beetle release

**Before and After**



July 2006

Sumter County location #1  
pre-release



June 2006

Sumter County location #2  
pre-release





July 2008

Sumter County location #1 two years after beetle release



June 2007

Sumter County location #2 one year after beetle release

Aug. 2005



Sumter County location #3  
pre-release

### **Is the biocontrol program working?**

Biocontrol will not completely eradicate TSA from an area. Ranchers should be aware that beetles will not always provide the results that they desire. If a rancher wants to completely eliminate TSA from a property, then beetles are not the solution. Additionally, there is evidence that the beetles are less successful as one moves further north in Florida. Finally, it takes from a few months to as much as two years to see appreciable reductions in TSA density – biological control requires a degree of patience. Factors which influence the success of the beetle include time of the release and climatic conditions during winter.

### **Integration of beetles with mowing and herbicides**

An integrated approach to TSA management may provide the most satisfactory result in the shortest amount of time. Along with beetles, mowing and herbicides can be effective tools for TSA control. However, care must be taken when using a combination of control tactics, as one tactic may influence the effectiveness of another. Herbicides do not





Sumter County location #3 two years after beetle release

cause direct mortality to beetles, but immobile immature life stages will suffer high mortality as they cannot migrate from a treated plant to an untreated plant. Mowing may cause both direct mortality to beetles hit by blades, and indirect mortality to immature beetles which cannot migrate from cut foliage to new plants. Following are some recommendations which may improve overall management of TSA.

### **Recommendations**

- Mow TSA plants in pastures BEFORE they fruit to minimize the number of seeds in pastures.
- If beetles are known to be present in areas to be mowed, setting the mower higher than normal may result in lower beetle mortality.
- Dense infestation of TSA in open areas can be effectively controlled with herbicides and/or repeated mowing. Beetle populations can be left undisturbed in hammock areas to build up, and eventually spread to more open pasture areas.

- Beetles are in diapause (a resting state) from about November to April. The use of herbicides or mowing during this period will have minimal effect on beetles which are in leaf litter under plants.

## Herbicides

**Dense infestations.** Milestone (active ingredient aminopyralid) and Forefront (active ingredients aminopyralid + 2,4-D) herbicides are the most effective for controlling dense stands of TSA. Read and follow all label directions. These herbicides possess postemergence control of existing plants and preemergence control of germinating seeds. University of Florida research has shown that Milestone and Forefront will control germinating seedlings for over 6 months after application.

The application rate for Milestone is 5-7 oz/A while Forefront is 2-2.6 pt/A. Although the lower application rates are highly effective on existing plants, the higher rates will provide more soil activity and are suggested if large amounts of TSA seed are present in the soil. Although mowing prior to herbicide application is not required, it is important to add a non-ionic surfactant (0.25% v/v) and apply in at least 20 gallons of water per acre.

Another option is to use Remedy (active ingredient triclopyr). When using Remedy, mow plants to a 3-inch stubble height as soon as possible to keep plants from producing fruit and seed. Repeat mowing when plants reach the flowering stage (50-60 days) through April. Fifty to 60 days after the April mowing, when plant regrowth is at the first flower stage (late May-June), spray Remedy at 1 qt/A + 0.25% v/v non-ionic surfactant in 40 gal/A of water.

Remedy does not possess soil residual activity, and follow up applications to control escaped or new seedlings will be necessary.

Regardless of which herbicide is used, regular scouting after treatment is necessary. TSA can produce fruit at almost any time during the growing season and give rise to hundreds of additional plants. It is important to monitor the fields to ensure that no plants are allowed to reestablish and produce fruit.

**Sparse infestations.** Areas with low TSA infestation should be targeted and each plant sprayed individually. Recommended herbicides for 95 to 100% control are as follows:

1. Milestone at 0.5-0.8 oz per 2.5 gal (15 to 20 ml per 2.5 gal) + 0.25% v/v non-ionic surfactant + color marker. (Use a color marker with the herbicide solution to avoid spraying the same plant twice, or not spraying a plant at all.)
2. Forefront or Remedy at 0.5% solution (50 ml per 2.5 gal) + 0.25% non-ionic surfactant + color marker.



When spot-spraying, cover the entire plant with spray solution to ensure herbicide uptake and maximum control. Allow herbicides to dry on plants 3-4 hours before rainfall. Monitor treated areas monthly and treat new TSA seedlings. Do not allow plants to produce fruit. Be sure to follow the guidelines for spraying volatile herbicides such as Remedy.

*(See EDIS publication SS-AGR-12 Florida's Organo-Auxin Herbicide Rule <http://edis.ifas.ufl.edu> for more information.)*

# Frequently Asked Questions

## 1. What are the advantages of using biological control?

Classical biological control, which involves the introduction of host specific natural enemies from the native range of a pest, is an environmentally safe and inexpensive method to control exotic plants like tropical soda apple (TSA). Once an agent is established at a site, populations are self perpetuating and spread with little human intervention.

## 2. What biological control agents are available for TSA in Florida?

The South American defoliating leaf beetle, *Gratiana boliviana*, was released in May 2003 in Florida. Since then, the Florida Department of Plant Industry, the UF/IFAS, and the US Department of Agriculture have been releasing this agent in Florida and neighboring states. Other insect herbivores are being studied or are going through the regulatory approval process required before release. These insects include two additional defoliating leaf beetles, *Gratiana graminea* and *Metriona elatior*, and the flower bud weevil, *Anthonomus tenebrosus*. Additionally, scientists at UF/IFAS have developed a plant virus which is very effective in controlling TSA, and is applied much like a herbicide. This product has the trade name SolviNix™ and is currently registered for experimental use.

## 3. Is the beetle going to feed on my garden plants or crops?

No. This beetle only feeds on TSA. Extensive studies of the host range of *Gratiana boliviana* conducted in the laboratory and field confirmed that this beetle only feeds on TSA.

## 4. TSA is in the same plant family as tomato, pepper, egg plant and potato. Are these close relatives of TSA at risk?

No. Scientists from the University of Florida and the US Department of Agriculture offered 123 different plant species to the beetles and found that they could survive only on TSA.

## 5. How can I help the *Gratiana boliviana* if it is already in my property?

If you see beetles on TSA plants on one part of your property, but not at another, collect adults from several plants in the infested area and move them to healthy uninfested plants. Beetles will start reproducing on these “nest” plants then spread to nearby TSA.

## **6. Can *Gratiana boliviana* eradicate TSA from my property?**

No. Research by University of Florida indicates that a reduction in TSA density is noticeable 1-3 years after the release of *Gratiana boliviana*. When conditions are very favorable for the beetle (good weather, nutritious plants, a large number initially released), a visible decrease in TSA density may occur even faster.

## **7. How can *Gratiana boliviana* be integrated with other TSA management tactics?**

*Gratiana boliviana* provides an environmentally friendly approach to TSA management. However, the beetle is not the only tool available. Registered herbicides and mowing are effective in reducing large infestations. Mowing reduces the biomass of TSA, and is especially effective if done before the plants begin to produce fruit. Some beetles will survive mowing and continue to feed on the lower parts of the plants which remain. These beetles will slow the recovery of TSA plants. Additionally, many ranches are a mosaic of open pastures and more closed hammock areas. TSA in hammock areas, which are difficult to access with equipment, can be reduced by beetles, while TSA in open pastures can be managed by mowing and herbicides. Over time, the need to control TSA in open areas will decrease as the beetles spread from hammocks.

## **8. Where can I get beetles for release on my property?**

Your local county extension agent can either get beetles for you or put you in contact with the agencies producing the beetles.

## **9. Where I can learn more about biological control of weeds?**

Biological Control of Weeds

<http://www.purdue.edu/envirosoft/lawn/src/pest/biological2.htm>

Natural Enemies and Biological Control

<http://edis.ifas.ufl.edu/IN120>

How Scientists Obtain Approval to Release Organisms for Classical Biological Control of Invasive Weeds

<http://edis.ifas.ufl.edu/IN607>

**For more information, visit**  
**<http://pesticide.ifas.ufl.edu/TropicalSodaApple/>**

# About the Authors

**Rodrigo Diaz**, *Post-doctoral Associate*

Biological Control Research and Containment Laboratory  
Indian River Research and Education Center  
University of Florida  
2199 S. Rock Rd.  
Fort Pierce, FL 34945  
Email: rrdg@ufl.edu  
Phone: 772-468-3922 x 228

**William Overholt**, *Associate Professor*

Biological Control Research and Containment Laboratory  
Indian River Research and Education Center  
University of Florida  
2199 S. Rock Rd.  
Fort Pierce, FL 34945  
Email: billover@ufl.edu  
Phone: 772-468-3922 x 143

**Ken Gioeli**, *Extension Agent III*

St. Lucie County Cooperative Extension  
University of Florida  
8400 Picos Road  
Fort Pierce, FL 34945  
Email: ktgioeli@ufl.edu  
Phone: 772-462-1660

**Brent Sellers**, *Assistant Professor*

Range Cattle Research and Education Center  
University of Florida  
3401 Experiment Station  
Ona, FL 33865  
Email: sellersb@ufl.edu  
Phone: 863-735-1314

**Julio Medal**, *Research Associate*

Department of Entomology and Nematology  
University of Florida  
Bldg. 970  
Natural Area Drive  
Gainesville, FL 32611  
Email: medal@ufl.edu  
Phone: 352-392-9807





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