MANAGEMENT OF PEST ANTS IN NURSERIES

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Endorsed by

Big Island Association of Nurserymen

Hawai`i Export Nursery Association

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BACKGROUND

Quarantine requirements for exporters of potted plants, flowers and foliage have become more and more stringent. It is easy to understand that moving plant pests from one location to another is detrimental to the nursery industry, but what about pests we have not previously thought of as plant pests? Many insects can hitch a ride with a potted plant, and while they may not harm the plant itself, introducing these pests to new locations can potentially cause other impacts.

Ants are one of these pests. They often do not harm the plants they live in, but some species can cause huge economic and ecological damage when they are introduced to new locations. One such species, the Red Imported Fire Ant (*Solenopsis invicta*) is such a threat that the USDA has specific quarantine requirements for producers moving plants from within the RIFA quarantine zone to locations outside this zone. These requirements include mandatory treatment of stock and potting medium.

Fortunately, Hawai`i does not currently have Red Imported Fire Ants. However, there are several other ant species present in Hawai`i that are subject to restrictions for movement of stock between islands and interstate.

This manual is a guide to current best-practice nursery management options that minimize the impacts of these ant species to export operations.

PROJECT FUNDING AND EXECUTION

USDA FARM BILL

The project has been funded by the **USDA Animal and Plant Health Inspection Service** through section 10201 of the 2008 Farm Bill. One of the priorities of the implementation strategy is to "safeguard nursery production", and this project was funded under that priority.

HAWAI`I ANT LAB

**The Hawai`i Ant Lab** is part of the Pacific Cooperative Studies Unit of the University of Hawai`i. Their charter is to prevent the entry of invasive ant species into Hawai`i, develop technologies to manage those ant species already present and work to eradicate them where feasible. The Hawai`i Ant Lab is the lead group in this project, working with the Hawai`i Department of Agriculture and Dr. Arnold Hara of the UH College of Tropical Agriculture and Human Resources.

PARTICIPATING AGENCIES

Two key industry groups have participated in the development of this manual. The Big Island Association of Nurserymen and the Hawai`i Export Nursery Association have both endorsed and supported the project.

BIOSECURITY IMPACTS OF PEST ANTS

Shipments of potted plants, foliage, or flowers that are infested with ants are subject to certain quarantine requirements depending on where they are being transported. As a producer, this could affect your business through seized shipments, liability issues, penalties and monetary losses.

REGULATORY REQUIREMENTS

Intra-island (local sale)
Most pest ants are not "regulated species" and therefore there are no regulatory restrictions on the local sale of plants infested with ants. There is one exception to this – Little Fire Ants (*Wasmannia auropunctata*). This is a regulated species under Hawai`i Revised Statutes (HRS150A) and Hawai`i Administrative Rules (HAR chapter 4-72). Knowingly moving material infested with LFA is an offense under these laws.

Inter-island sale
The movement of potted plants, foliage, flowers and propagative material from one island to another within the State of Hawai`i is regulated by the Hawai`i Department of Agriculture Plant Quarantine Branch. All shipments must either be inspected by an HDOA inspector, or shipped from a nursery certified by the HDOA. In addition to other quarantine pests, inspectors will check for Little Fire Ants. Infested material cannot be shipped until it has undergone quarantine treatment. The shipment may be re-inspected at the destination island by HDOA inspectors located there.

Mainland USA

The provisions relating to inter-island shipments apply, and additionally, State laws or regulations in the receiving state also apply. In most cases, agriculture or quarantine staff in the receiving State inspects incoming shipments also. At this point, detection of any pest ants may trigger a seizure, destruction of the shipment, or return to the origin port.

Hawai`i Revised Statutes HRS150A can be viewed online: http://www.capitol.hawaii.gov/hrscurrent/Vol03_Ch0121-0200D/HRS0150A/HRS_0150A-.htm

Hawai`i Administrative Rules HAR can be downloaded here: http://hawaii.gov/hdoa/admin-rules/subtitle-6-division-of-plant-industry/4-72%20HAR-2012

EXPORT CERTIFICATION

Producers can opt for HDOA nursery certification. This allows growers to export without inspections of individual shipments, and is based on phytosanitary inspections of the benches and/or growing area of stock bound for export. HDOA Plant Quarantine officers will conduct at least two inspections every year to determine whether the export section of the nursery meets required standards. For more information about nursery certification, contact your local HDOA office or go to:

http://hawaii.gov/hdoa/pi/pq/export.

FUNDAMENTAL APPROACH TO MANAGING PEST ANTS

IPM – COMBINING PHYSICAL, MANAGEMENT BIOLOGICAL AND CHEMICAL SOLUTIONS

Integrated Pest Management or IPM is a pest management approach that utilizes all available pest management methods to keep pest populations below pre-determined thresh-hold levels. Each pest management technique must be environmentally sound and compatible with producer objectives. IPM has several components that work together to allow the grower to develop the most efficient and effective pest management strategy:

1. Setting pest thresh-holds,
2. Survey and scouting,
3. Developing a multi-pronged pest management strategy, and
4. Monitoring outcomes.

SETTING PEST THRESH-HOLDS

Often, the presence of some pests in a production system causes no economic harm, and sometimes, the presence of even one pest individual is too many. In the case of pest ants as a quarantine problem means the pest thresh-hold must be zero. Where pest ants are causing other problems like farming scale insects or mealybugs, the presence of small, scattered colonies may not actually be causing any real economic damage.

Knowing what pest loads are present and the identity of the species is therefore an important factor in deciding whether to take action or not. The best way to get this information is through regular scouting or pest surveys.

Survey and scouting

Regular survey and scouting are essential in any integrated pest management system. Surveying for ants is not difficult and there are three good methods of doing so. In Hawai`i, where it is warm all year round, these surveys should be conducted several times a year (at least twice).

1. Visual searching

Pick up random pots at regular intervals and look underneath each pot. Check out both the underside of the pot and that part of the bench where they have been sitting. Any ants scurrying away can be caught using a piece of scotch tape. Simply press the tape down onto the ant and stick it onto a piece of paper. A more thorough inspection entails taking the pot to a solid bench and slapping it down sideways (not enough to damage the plant, but sufficient to dislodge any ants crawling on foliage) If plants are pot-bound, removing them from their pot and tapping the root-ball onto the bench will also dislodge any ants living in the potting medium.

2. Survey for Little Fire Ants

There is a protocol for survey of Little Fire Ants in the Appendices on page 12. This entails placing chopsticks or popsicle sticks smeared thinly with some peanut butter into shady spots around the nursery. Intervals of 20-30ft are ideal. Leave the chopsticks for about 60 minutes, and place them into zip-lock bags. It is helpful to use several bags – one for each part of the nursery because that way it will be possible to narrow down the location of any problem ant species.

3. Complete ant survey

Different ant species are attracted to different kinds of food items. Some like sweet things, other prefer proteins and some like oils. A survey for all ant species means it is necessary to use three different kinds of baits. This can be done by modifying the Little Fire Ant survey to use different bait types. Instructions for this can be found on page 13. After the survey, they can then be sent to the Hawai`i Ant Lab for identification.

Pest identification

Ants are unusual in a pest management context because there is no one-size-fits-all solution. Each ant species has a unique biology and often solutions need to be tailored to suit each individual species. For this reason, knowing which ant species are present in your production system is very important. We have over 60 ant species in Hawai`i, and most of these are not nursery pests. Only a handful poses problems for the nursery industry. A brief description of the main pest species can be found on page 18. Fortunately, there are many identification resources available to growers. The Hawai`i Ant Lab and Hawai`i Department of Agriculture are all too pleased to provide identification of any ant species you might find during your scouting and survey activities. There is an illustrated key to all ant species in Hawai`i on page 21. Once you know the identity of the ant species in your nursery, you are in a much better position to develop a plan of action.

The presence of some ant species may pose no biosecurity or regulatory issues at all, and it is then up to you to determine if they are causing any impacts to your stock. Other ant species can pose substantial problems, especially for inter-island and interstate exports. The most serious of these is the Little Fire Ant. However, interstate agriculture agencies are becoming increasingly cautious about the presence of any ant species.

PHYSICAL FACTORS

NURSERY DESIGN AND LAYOUT

The nursery "industry" in Hawai`i is very diverse and ranges from large, high-volume wholesale enterprises, smaller retail establishments that sell direct to the public, to hobbyists who grow plants and sell them at farmers markets and other venues. Your nursery layout has probably "evolved" over the years as your business grows, shrinks, or changes according to market demands. The gradual changes to nursery layout over time result in three key design elements that hamper pest management.

The first is the lack of a **clear boundary** between the growing area and neighboring properties. Ants do not respect boundaries, and without a clear buffer between your business and neighbors, it can be difficult to manage pest ants. You may be very successful at eliminating an ant problem in your business, but if those ants can re-infest your property from neighboring land, all your efforts could be wasted. If at all possible, establish a cleared buffer around your enterprise. Wider is better, but at a minimum, this should be 6 feet or better. This buffer can be utilized as a "fire-break" between you and the ants beyond.

The second common design element many nurseries have, is the use of **wind-breaks** or planted areas through the nursery or adjacent to greenhouses or growing areas. These windbreaks often contain palms and other tropical trees. While they may look attractive and serve a useful purpose, they are also a harborage for pest ants and other plant pests. Often it becomes very difficult to manage ant populations when windbreaks are close to growing areas.

A final aspect of nursery layout that can hamper pest management is the presence of "fallow" areas – growing beds or shade-houses containing old pot-bound stock, accumulations of supplies and equipment that are not being used, and unused space in general. This build-up of "stuff" that might be useful one day and unused growing beds or shade-houses are a haven for pest ant populations to establish and develop. Because these areas do not get much attention, they serve as a quiet place for pest populations to build-up unnoticed.

So, wherever possible, change your layout so you have a cleared buffer around your operation, remove unnecessary windbreaks and other vegetation, and keep unused areas of the nursery as tidy as possible. These simple changes will greatly reduce the cost and time needed to manage pest ants in your operation.

HABITAT REDUCTION

The previous section deals with changing the basic layout of a nursery operation to reduce the amount of effort needed to manage nursery pests. It goes hand-in-hand with reducing available habitat. Nursery operations can be frantic and diverse as you respond to market demands. Growing a number of different products with market demands that ebb and flow often results in an accumulation of equipment and supplies necessary for each aspect of your business. One day you need a 1000 1 gallon pots and next week demands change and the left-over pots sit somewhere gathering moss – and pest ants. Accumulations of pots, cinder, peat and other supplies that are left idle until they are needed, provide excellent habitat for pest ants to establish and spread. Often these piles of unused items are left adjacent to growing beds, shade-houses, etc. where they pose the biggest threat to your growing stock.

Wherever possible, keep these items organized, and if possible in some central location away from production areas. Spaces around shade houses etc. should be clear of equipment, supplies and dunnage. Not only does this prevent ants from sneaking in to your stock, it will make managing these pests much easier and more cost effective.

MANAGEMENT FACTORS

STOCK AND GOODS INWARD

One of the main pathways for pest ants to enter your nursery is through goods moving into the nursery production system from elsewhere. Items such as stock, pots, potting media, landscaping material, items for resale, etc., all potentially harbor pest ants. Any materials coming onto the property should be first held in a quarantine area and inspected or surveyed to ensure they are ant free. Refer to the survey protocols at the end of this manual for appropriate methods. Plants being purchased or returns from customers or landscaping projects can also potentially become infested while they are outside your nursery. These should also be quarantined and surveyed.

Trucks, machinery and employees' vehicles can also harbor ants. Again, ensure a designated car park is used for these vehicles and either survey regularly, or better yet, treat with barriers sprays every 4-6 weeks.

WORK FLOW, PRODUCTION FLOW

A defined work flow is also important, especially when you have production or growing areas you use to harvest cuttings and other propagule material. It's a good idea to chart out how things move around within the nursery and keep these flows well-defined. As stock moves from one part of the production line to the next, there are different risks of contamination. If there is a pest problem that becomes too difficult or expensive to control, it may be possible to design a management plan in which some areas early in the production chain receive less treatment, with control gradually strengthened as the product approach their final stages.

CHOOSING BATTLE LINES

Nursery enterprises are sometimes very large and can span many acres. Treating these larger enterprises can be costly and time consuming. An alternative might be to choose your battle lines and leave certain parts of the property untreated. This approach can work well, especially when planned in conjunction product work flows. The important thing is to have pest-free plants at the end of the production chain, and sometimes it is possible to do this without the need to treat the entire operation.

BIOLOGICAL SOLUTIONS

For many insect pests, the introduction of natural predators or pathogens is the most effective and least costly solution. There are thousands of very successful biocontrol programs that save agriculture millions, even billions of dollars per year. However, most insect pests are solitary – they live out their lives with little or no contact with other insects (except for mating). This means a natural predator, for example, can reduce the pest problem one insect at a time.

Ants are one of the few insect families that live together in a social colony. Each ant has a specific task, and most foraging ants (the ones we actually see) are the older workers assigned to the high-risk task of finding food. A large portion of the colony stays out of sight. All the workers are sterile daughters of a queen. The workers protect the queen

and normally she is very difficult to find.[1] If some workers are killed during foraging, by a natural predator for example, the queen simply lays more eggs to replace those lost workers.

Research of potential biocontrols against Little Fire Ants is in its infancy and to date, no potential candidates have been identified and tested. The history of biological control efforts against ants in general has met with mixed success. Three or so species of phorid fly have been released in southern USA to combat the Red Imported Fire Ant (not the Little Fire Ant). They appear to have established well; however, the impact on the Red Imported Fire Ant population has been only slight. Other agents that have been researched for their effect on Red Imported Fire ants include several species of protozoa and a species of fungus. This work has been progressing for some years but at this time has not resulted in a miracle cure. However, together, all the biocontrols will reduce the total Red Imported Fire Ant population somewhat, but not eliminate them.

CHEMICAL TREATMENT OPTIONS

WHOLE OF NURSERY (NURSERY **NOT** CURRENTLY INFESTED WITH ANTS)

If there are no ants of quarantine concern present in the nursery, it is good practice to keep it that way. This avoids having problems at a later time. There are two activities that a grower should do:

1. Regular surveys of the nursery
2. Bait or chemical treatment of the nursery boundary.

Surveys

There are three ways that ants can enter the nursery system: purchase of infested plants, potting media or other items; ants traveling on cars and trucks driven by staff, customers and delivery vehicles; and ants spreading from a neighboring property. Good nursery quarantine procedures, hygiene and designated parking can reduce the risk of the first two pathways, but natural spread from an adjoining property is more difficult. It is important to conduct regular surveys of high-risk areas within the nursery, such as: car parking areas, quarantine areas and the nursery boundaries. This can be done quickly and easily using the survey procedures on page 12 of this manual. The recommended frequency of this survey type would be 2-4 per year, with at least one survey conducted over the entire property. These survey activities should be backed up by regular treatments around the boundaries and the car parking areas.

Prophylactic treatment

Prophylactic treatment refers to treating an area for a pest although it "probably" is not infested. It's a good approach to take, because ant infestations, when colonies are just starting to spread, can be very difficult to detect with a survey. These treatment types can be done using baits or spraying residual pesticides. Baits are preferable, less expensive and easier to apply.

WHOLE OF NURSERY (NURSERY **IS** CURRENTLY INFESTED WITH ANTS)

If ants of quarantine concern have infested the nursery, there are two options open to the grower. The first option is to eradicate the ants from the entire nursery. The other option is to eradicate the ants from those sections of the nursery that are most critical – the export benches, packing and processing areas.

Treating an entire nursery is preferable, because there is greater certainty that any plants sold or moved from the nursery are ant free. Depending on the type of operation being carried out, either baits, chemical sprays or both can be used. Baits tend to be least expensive, take less time to apply and are more effective over larger areas. An additional benefit is that far less insecticides are used, because baits are directly targeted at the ant rather than being applied everywhere.

However, some operations are better suited to treatment by residual insecticides.

PROTECTING STOCK

Although it is preferable to have an ant-free nursery, and therefore ant-free plants, there may be times when the grower has stock that is infested. Plants and the potting media can be treated prior to sale or export to ensure they are ant free. There are three

[1] Some ant species, for example Little Fire Ants, can have many queens within each colony.

main methods for treating plants: dip, drench and spray with an insecticide; adding controlled release chemicals to the potting media before use, and heat treatment immediately prior to shipment. Each has advantages and disadvantages.

Dip/drench/spray options

Ants can nest and live in either the potting medium or the foliage of potted plants (sometimes both). Therefore the entire plant needs to be treated. Though some pesticide labels allow foliar application, few allow for dip or drench applications. In addition, not all products are labeled for edible crops. **Be sure to read and follow the pesticide label.** Here are some examples of effective products:

Sevin®
Sevin is a trade name and a number of products are registered under that name. It contains the active ingredient carbaryl. Treatment recommendations are for Sevin RP4®, (EPA reg. 264-335) which is labeled for this purpose. Sevin can be used as a foliar spray on some plants. It provides short-term control. Foliage sprays are mixed at a rate of 1.5 oz per gallon.

Talstar Select®

This product (EPA reg. 279-3155) is registered for use in nurseries by licensed applicators only. It can be used as both a spray and a drench for potted plants; however, the rate depends on the bulk density of your potting medium. Talstar Select®, applied at this rate provides up to six months control of insects in the potting mix. To calculate your bulk density, use a measuring jug and fill it exactly to the one quart mark with your potting mix compacted as you would for a potted plant. Dry the measured amount in an oven turned on low until no water remains and the mix is perfectly dry. Weigh the dry mixture using a postal scale or good kitchen scale. The chart below shows how many ounces Talstar Select®, to add to 100 gallons of water. If you use a measuring jug that is oven-proof, you could weigh the jug before filling it and subtract the container weight after weighing.

For both Sevin® and Talstar Select®, there may be equivalent generic versions available at your chemical supplier.

Weight of 1 quart dried medium (oz)	Ounces Talstar Select per 100 gallons water
6.9 or less	24
7.0-11.5	4.8
11.6-20.7	7.2
16.2-20.7	9.6
20.8-25.3	12.0
25.4-30.0	14.4

Each pot needs to be drenched with at least 1/5 of the pot volume for treatment to be effective.

Potting media treatment

It is possible to "pre-treat" the potting medium of some nursery stock. Granular products such as Talstar Nursery® and generic equivalents are available, and can be used without the need for an applicator license. These products can be dosed to exclude ants for a period exceeding two years. Again, the bulk density of the potting medium determines how much Talstar Nursery® will be needed. Also, more product is required as the desired length of protection increases. Use the table below to calculate how many pounds need to be added to each cubic yard of potting medium.[2]

Weight of 1 quart dried medium (oz)	lbs Talstar Nursery per cu. yard			
	6 mth	1 yr	2 yr	>2yr
6.9 or less	1.0	1.2	1.5	2.5
7.0-11.5	2.0	2.4	3.0	3.5
11.6-16.1	3.0	3.6	4.5	7.5
16.2-20.7	4.0	4.8	6.0	10.0
20.8-25.3	5.0	6.0	7.5	12.5
25.4-30.0	6.0	7.2	9.0	15.0

[2] This product cannot be used on plants already potted-up. It must be added to the potting mix before use.

Heat treatment

Dr. Arnold Hara and his team at the Komohana Extension Center (UH College of Tropical Agriculture and Human Resources) have developed novel heat treatment systems that can eliminate most, if not all living ants from potted plants. The system relies on heating the plant and pot to a temperature hot enough to kill ants but not hot enough to harm the plants. Dr. Hara can be contacted through his web page here: http://www.ctahr.hawaii.edu/haraa/

Hot water dip tank for treating nursery plants[3]

Hot water spray room for treating nursery plants[4]

[3] Image provided by Dr. Arnold Hara, CTAHR
[4] Image provided by Dr. Arnold Hara, CTAHR

APPENDIX 1. ANT SURVEY METHODS

SURVEY TO TARGET LITTLE FIRE ANTS

Little Fire Ants (LFA) are the main ant species of quarantine concern for nurseries on the Big Island. A survey to identify if these are present in your nursery is fairly quick and easy using lures. Ants are always foraging around looking for sources of food. By placing the right type of food item at regular intervals, a foraging ant will quickly find it, and soon the other ants in the colony join her in retrieving the food. By using lures, the ants come to you, rather than you having to search for them. The best lure for LFA is peanut butter, because they need the oils and proteins to feed the queens and the larvae.

You will need the following items:

1. Creamy peanut butter – LFA seem to prefer the cheaper brands of peanut better most
2. Chopsticks (cut in half), coffee stirrers, or popsicle sticks
3. Zip-lock bags
4. Bright-colored spray paint (fluorescent pink or orange is best) – optional

Conducting the survey

The chopsticks can be rather hard to find after they are distributed around the nursery, so it's best to mark them using spray paint (pink or orange is a good color), so they can be easier to find. Once painted, smear the lightest amount of peanut butter onto the chopsticks, coffee stirrers or popsicle sticks, and place them at approximately 15 foot intervals in a rough grid pattern through the area to be surveyed. Leave them out for one hour or so, then go back and retrieve them. Place any chopsticks with ants on them into a zip-lock bag.

Ideal spots to place lures include the following:

- The base of plant benches
- On the media of potted plants
- The bases of trees
- In the crowns of palms or at the bases of older leaves on bananas,
- At the edges of buildings (especially the northern and eastern sides)
- Near or under piles of tree trimmings, stacks of old pots, cracks or splits in weed matting
- Under trees in wind breaks

You can divide the nursery area into sections and place all the chopsticks from one section into the same zip-lock bag. Don't forget to write the location onto each zip-lock bag. Once you have collected all the lures, place the bags in the freezer overnight and bring or mail them to the Hawai`i Ant lab for identification:

Hawai`i Ant Lab
16 E. Lanikaula Street
Hilo, HI 96720

A typical Little Fire Ant lure - chopstick with peanut butter placed in a shady area on the ground

Little Fire Ant lure deployed on a banana plant

Tips for a better survey

- LFA like shady moist places – always try to place the lures away from the sun
- If you have a banana patch or palm trees, place at least some lures in these. The best location is where the older leaves join onto the stem, as well as in the leaf litter at the base of the plant.
- LFA are VERY small, a uniform orange color and walk fairly slowly. If the ants you see are black, fast moving or are more than one color, they probably are not LFA.

Little Fire Ants are

- Very small – probably the smallest ant you have seen
- An orange-red color all over
- Very slow moving unless disturbed
- Will often fall from the chopstick as you pick it up

Images of Little Fire Ants on lures

SURVEY TO TARGET ALL ANT SPECIES

Every ant species has a preferred type of food. Peanut butter works well for ants that like proteins or oils, but some ants prefer sweet foods and other ant species like only proteins. In order to survey for all ant species, it is necessary to place a wider variety of lures.

The survey method for Little Fire Ants is quick and easy. It can be modified to capture a wider variety of ant species by placing a wider variety of food types.

For this type of survey, you will need the additional items:

- Cane sugar or karo syrup
- A can of tuna or similar fish

Using one part cane sugar or karo, blend with 3 parts warm water to make a light sweet liquid. Blend the canned fish in a separate container with enough water to make a thin slurry (like a fish smoothie). Prepare ⅓ of the chopsticks by placing the unpainted ends in the sugar mixture for at least an hour. Do the same for the fish mix, and prepare the peanut butter sticks as usual. The watery sugar mix and the fish mix will soak into the chopsticks and they can be lightly patted dry to make them easier to handle.

Now conduct your survey as before, but place the different lure types in an alternating pattern: one peanut butter, then a sugar lure, then fish. Collect them as before. The fish lures will become unpleasant to handle if left unfrozen, so please make sure to leave them in the freezer until just before bringing or mailing them in for identification.

APPENDIX 2. CONTROL OPTIONS IN NURSERIES: BAITS AND RESIDUAL SPRAYS

The array of insecticides on the shelf at your local garden store can be mystifying. There are dozens of different proprietary products available, and it can be very difficult to know which is the right one for your situation. Some are liquids, some are granules, they can be in small bottles or huge bags, in ready to use spray bottles or concentrates…So, which one do you buy?

BAITS, BARRIERS AND CONTACT SPRAYS

Pesticides for ant control can be divided into three main types: baits, barrier treatments and contact sprays. Each of these work differently and it is important to know which is which.

Ant baits

Baits are an attractive food laced with a toxin (usually a very small amount). Most baits for outside use are in a granular form to make them easier to spread. Liquid baits are mostly used inside a home in bait stations. Ants harvest baits and take it back to the nest where it shared with the rest of the colony. Once the toxin takes effect, most or all of the ants are killed. Different ant species prefer different food types, so it is important to match up the bait with the ant species you are trying to control.

Baits are the recommended first-line treatment, because they are very effective and also minimize the use of pesticides.

Most baits for outside use are in a granular form to make them easier to spread. The granules are usually made from corn grits that have been soaked in oil, and then toxin is added to these during manufacture. Although they are not harmful to pets and other animals, birds and chickens might find them attractive. If you have chickens on your property, remove them from the sites you are treating or spread the granules late in the afternoon just before your chickens roost.

Barrier treatments

Barriers can come in a spray form or a granule, and can be applied to the soil, hard surfaces or vegetation. They contain a toxin that has a residual effect and can stay active for a month or even longer. Once they are deployed, any ants that wander across a treated surface will come into contact with the chemical and die.

It is easy to confuse granular barriers with granular baits, so it is important to read the label carefully. Many granular barriers contain synthetic pyrethroids. The active ingredient list will usually contain one or more chemicals with names ending in "- *thrin*", like "bifenthrin", "cyfluthrin" etc. Granular barriers also need to be watered before they are activated, while water often inactivates baits.

Contact sprays

Contacts are used to directly spray a target pest. They are useful for spraying spiders, flies or other bugs that you discover in your home. Often contact sprays are sold in pressurized aerosol cans which can be aimed at the offending insect or spider.

BAIT THEM FIRST, THEN BLAST THEM

The best way to manage Little Fire Ants is to use a dual approach of baiting and barrier treatments. It is important to use them properly, because even small differences to your application method can lead to big differences in results. First, NEVER apply a bait and a barrier treatment at the same time. Why? Well, baits work when ants bring them back to the colony and share them with all the workers (and also to tell the others where to get more bait). If a worker ant is carrying some bait back to the nest and crosses over a barrier treatment, she will die before being able to get back to the colony. One treatment will cancel out the other and you will be wasting your hard-earned cash.

So, bait first and give the baits enough time to have an effect – few days are sufficient; then, if you choose, apply barrier treatments. Continue baiting every 4-6 weeks for at least a one year period, and re-apply barrier treatments as needed (according to the label).

- ***Read the label***
- ***Do not use old bait***
- ***Treat in dry weather***
- ***Treat your entire property***

Always read the label directions for the product you intend to use. The label is a legal document and specifies what you can and cannot do. It will also list any precautions you should take and any personal protective equipment (PPE) you should wear while mixing and applying the product.

The baits most suitable for control of Little Fire Ants all look very similar – small yellow granules around ⅛ inch in size. The granules are actually corn grits which have been infused with vegetable oil and a toxin. They are most easily spread using a small fertilizer spreader.

Once the bottle has been opened, the baits will quickly deteriorate and become rancid, so you should use any opened container within 2-3 treatments. Bad bait will not be attractive to ants and they will not feed on it. Most baits come in different pack sizes, so buy the size that is sufficient to treat your property. This way your bait will always be fresh.

Rainfall makes the bait soggy and unattractive to ants. Try to pick a dry day for applying baits. In places where this is difficult, a dry period of around 4 hours after treatment should be sufficient time for ants to find the granules and share with the nest. After a day or so, the baits are no longer effective, even without rainfall.

One mistake a lot of people make is to only spread bait in places where they have "seen" ants. It is very important to treat your entire property, because LFA have lots of small nests and often we do not know where they all are. So, walk over the entire property and systematically apply the bait to every section. This is actually quite easy to do if a small seed spreader is used.

These are available at low cost from hardware and pesticide stores. They feature a hopper for holding the bait, a winding handle that agitates the bait and scatters it over the ground, and an adjustable aperture that is used to calibrate output. These spreaders are also used to scatter seeds and fertilizer.

Typical hand held bait spreader showing the winding handle and the aperture adjustment. Set the aperture at "1".

With the aperture set at "1" (see above) turn the spreader handle at approximately ½ to 1 revolution per step while walking at 2-3 mph. The bait will fling out and create a swath of about 4 yards. Remember, not a whole lot of bait is needed and often it is spread so thinly on the ground, it seems you have not put out enough. Don't worry – there will be enough bait there. When applying the bait over your property, an overlapping series of parallel swathes is recommended. This is accomplished by starting on one boundary of an infested site and proceeding one yard inside the boundary.

Example of a treatment path taken by an operator treating around an urban structure.

Once you reach the property boundary, take 2 paces towards the untreated area and return parallel to the original path, working around buildings and other obstacles. Continuing this process, you will be able to systematically cover the entire property in just a few minutes. It is important that all ground is treated including spaces between buildings and corners of gardens. An additional sweep around buildings, garden edges and other structures is a good idea because more ant colonies live in those locations. Rainfall within 4 hours of treatment will reduce effectiveness so plan to conduct treatment when rain is not expected for 4 hours.

Another common mistake is to bait again too soon. The ants that survived the first round of baiting can remember that those little yellow granules made them sick last time, and will actually avoid taking your baits the next time around. Wait about 4-6 weeks before using baits again.

The Hawai`i Ant Lab has tested several bait products available in Hawai`i. Some are good and others, not so good. The following bait products are ***labeled for use in commercial nurseries***:

- **Maxforce Complete®** is sold at chemical supply companies and has a very attractive bait matrix, including a sugar, fat and protein attractant. It is a little more expensive than other products but we have found it to be extremely effective.
- **Siesta™ Insecticide Fire Ant Bait** is sold at chemical supply companies. It is a little more expensive than other products but it appears to remain attractive to ants even after it gets wet unlike other granular baits.
- **Firefighter®** is a granular bait recently registered for use in Hawai`i. It has the active ingredient of Spinosad, and has some edible crops on the label.

If you are treating edible crops, be sure they are included on the label.

Some other baits you may encounter have been tested and found to be less effective than other products, such as: Extinguish Plus® and Advion® fire ant bait.

BARRIER TREATMENTS

- ***Read the product label***
- ***Do not mix barrier treatments and bait treatments***
- ***Use a different spreader when using granular baits***
- ***Granular barriers must be wetted to become active***
- ***Application rate varies, see label for application instructions***

Always read the label directions for the product you intend to use. The label is a legal document and specifies what you can and cannot do. It will also list any precautions you should take and any personal protective equipment you should wear while mixing or applying the product.

Barrier treatments are insecticides that come in liquid or gradual form and are sprayed or sprinkled around areas where ants are to be excluded. As ants and other insects crawl over the treated areas, they come into contact with the toxin and are killed. Barrier treatments usually have a residual activity and can provide protection for months.

Granular barrier treatments can be spread using a simple fertilizer spreader, just like baits. However, it is good practice to have 2 spreaders – one for use with baits and the other for the barrier treatment (mark each one with a marker pen so you know which is which). If you use the same spreader for both jobs, it is possible you might taint the baits with traces of the barrier granules. The ants could be repelled by the smell of the barrier granules and not feed on the bait. The chemicals in granular barrier treatments need to be wetted to become active. This helps the binding process needed for the chemicals to work.

A reminder here that it is not a good idea to apply a barrier treatment at the same time as bait, because the ants carrying the baits back to the nest will be killed before they have a chance to share it with the colony. Always apply the barrier treatment a few days after you have applied baits.

DEALING WITH ANTS AROUND FOOD PLANTS

Many pesticides are not registered for use on food plants. This is because the Environmental Protection Agency has very strict guidelines for registering pesticides to be used on crops. Therefore, there less products available for treating ants in food crops, and often a product will be registered for one crop but not another. Usually the "popular" crops have more products available, but unfortunately for growers in Hawai`i, the crops and fruits we grow here are often not on product labels. Chemical companies are required to carefully test their products for residues in each crop they wish to list on their labels, and each test can be very expensive. Many crops and fruits grown here in Hawai`i are not grown anywhere else in the USA and the cost of testing these is too great to make it economically worthwhile for the companies.

There are several bait products available in Hawai`i registered for use on a broad range of crops. However, be sure to read the label carefully to make sure your crop or fruit is listed. You can download product labels mentioned in this document by going to the Hawai`i Pesticide Information Retrieval System (HPIRS) maintained by University of Hawai`i College of Tropical Agriculture and Human Resources at Manoa. Baits available for use on or near food plants include the following:

- **Tango™** is registered for use on and under food plants also. It contains the insect growth regulator Methoprene and may be mixed in a bait matrix of your choosing. This product appears to be very effective and safe. Please read Fact Sheet 8 to understand how Tango™ works to find out if it is right for you.
- **Siesta™ Insecticide Fire Ant Bait** can be used on stone, pome, citrus and nut trees.
- **Firefighter®** is a granular bait recently registered for use in Hawai`i. It has the active ingredient of Spinosad, and has some edible crops on the label.
- **Insecticidal Sprays** may also be used on food plants, though they are more effective as spot treatments or for small areas. Most insecticidal sprays are general insecticides which will kill other insects as well as ants. There is a wide variety of organic and conventional products available in concentrates and ready-to-use formulations. When choosing an insecticidal spray, read the label carefully to make sure it is right for your situation and to know how to properly use the product for effective pest control.

CONTROLLING ANTS IN TALL VEGETATION

Safety precautions for all pesticides

ALWAYS *read the label of the product you buy very carefully to make sure your plant species and situation is listed.*

Follow ***ALL*** *safety directions on the label.*

ALWAYS *make sure to keep other people and pets away from the treated plants until they are completely dry*

Little Fire Ants often nest in the foliage and branches of trees. These may not be well controlled with standard bait applications, because the tree-dwelling ants do not always forage on the ground. Most baits are granular and so cannot be applied to trees. Hawai`i Ant Lab's gel baits with **Tango™** can be applied to trees, so this is virtually the only effective bait option in trees. For more information on the Hawai`i Ant Lab Gel Bait, see HAL Fact Sheet 8.

APPENDIX 3. TARGET SPECIES BIOLOGY

LITTLE FIRE ANTS

Scientific name:

The scientific name for this species is *Wasmannia auropunctata*. Around the world it is also known as the "cocoa tree ant" and the "electric ant".

Origins:

Little Fire Ants (LFA) are originally from south America, east of the Andes. It has been spreading around the world for over 100 years.

Known distribution:

USA (Florida), Caribbean islands, west Africa, Israel, Papua New Guinea, Solomon Islands, New Caledonia, French Polynesia, Hawai`i, Australia, Galapagos, and Guam.

Biology:

Little Fire Ants are a rainforest species, and nest on the ground, in leaf litter and in vegetation. They have many small inter-connected nests rather than one main colony. Instead of a single queen, Little Fire Ant colonies have many queens – each laying eggs. This results in a virtual blanket of nests reaching from the ground to the canopy. They prefer sites that are shaded, warm and moist, and generally avoid full sunlight.

Nurseries and potted plants (especially under shade) are a perfect habitat for this species. Each potted plant can contain one or more nests in the potting medium, under the pot and in the plant being grown. Often nursery benches are supported by cinder blocks and the gaps between these blocks also host other colonies. Each potted plant, when moved, can start a new infestation at its destination.

The predominant sources of food for this species are the sugars produced by scales, mealybugs and other homoptera like whiteflies and aphids. Little Fire Ants "ranch" these plant pests, moving them to new locations and protecting them from their natural enemies.

Impacts:

The association between Little Fire Ants and homopteran plant pests can cause damage to the hostplants and reduce productivity of fruiting trees and reduced growth of ornamental plants. Additionally, Little Fire Ants have a painful sting, and infested sites often have many millions of these ants per acre. Ants foraging on vegetation often fall to the ground and on people or pets. It is common for people in infested areas to suffer repeated stings on the neck, shoulders and torso.

Domestic pets can be blinded by repeated stings on their eyes. Once Little Fire Ants become well established in a new location, they will invade homes in search of food and new nesting sites. In these situations, people are often stung in their beds and children often become victims.

By this stage of development, it is almost impossible to eradicate them and residents are forced into a continuing cycle of repeated applications pesticides. Some people choose to move to uninfested locations in order to avoid this problem.

WHITE-FOOTED ANTS

Scientific name:

The scientific name for the White Footed Ant is *Technomyrmex dificilis*. This ant was previously identified as *Technomyrmex albipes* until 2007. It is also known as the "Black House" ant around the world.

Origins:

Native to Southeast Asia, White Footed Ants have spread throughout the world mainly through the transport of cargo and other commodities.

Known distribution:

USA (Florida, South Carolina, Georgia, Louisiana, Hawai`i), Antigua, Nevis, Puerto Rico, St. Croix and St. Thomas. In Hawai`i WFA is currently known from Maui,Oahu and Kahoolawe. This species is a part of group of *Technomyrmex* species that look almost identical to one another, so it is probable this species may be established on other Hawai`ian Islands.

Biology:

White Footed Ants (WFA) will nest in almost any location inside and outside of the house including under roofs, cardboard boxes, compost piles, potted plants, outdoor furniture, etc... but trees seem to be ideal. Colony sizes can range from 400,000 to 3 million individuals. Because of the enormous size of the colonies, large amounts of food are essential to

sustain the populations. WFA will feed on a wide variety of food sources including sugary substances and dead insects.

Unlike many other ant species, WFA do not share food with the rest of the colony. This makes control with baits very difficult because only about half of the colony will be killed (those ants that foraged on and ate the bait). The sterile female worker ants lay unfertilized eggs ("trophic eggs") which are used as a food source for the non-foraging ants in the colony.

Like other "tramp ant" species, WFA spread rapidly through movement of infested material such as household waste, plant material, potted plants, etc. They have enormous reproductive capabilities and new colonies within an area are founded via swarming aswell as budding (a subsection of the colony moves to a new location with a queen to begin a new colony).

Impacts:

White Footed Ants (WFA) do not bite or sting. They are considered a pest primarily due to their sheer numbers, which can seem never ending. WFA are also known to tend Homopertan plant pests such as scale insects, aphids and mealy bugs and feeding on the sweet sugary honeydew produced by these insects. It has been documented that this association has contributed to the spread of several serious plant diseases around the world. Because WFA are very attracted to sweets they are considered a major nuisance in homes, gardens, greenhouses, and orchards.

ARGENTINE ANTS

Scientific name:

The scientific name for Argentine Ants is *Linepithema humile*. Until about 20 years ago it was known as *Iridomyrmex humilis.* Worldwide it is known as the Argentine Ant.

Origins:

As its name suggests, this species was originally from south America with its native range centered on theParaná river catchment which spans Brazil, Paraguayand Argentina.

Known distribution:

Argentine ants have been widely distributed by human commerce during the early part of the 20th century and are now found worldwide, including Europe, USA, South America, Australia, Africa and Asia as well as many islands in the Pacific.

It is a common species on all the islands of Hawai`i and is usually found at mid-high elevations. At lower elevations, it is out-competed by Big-Headed Ants.

Biology:

This species prefers a Mediterranean climate with warm dry summers and cool wet winters. However, in the absence of competition from other ant species, it can establish and thrive in warmer and cooler climates.

Impacts:

Argentine ants are a serious ecological pest, disrupting native ecosystems and is also a structural pest – often invading homes and urban buildings.

SINGAPORE ANTS

Scientific name:

The scientific name for the Singapore Ant is *Monomorium destructor*. It is also commonly known as the "destructive trailing ant" and "mizo-hime-ari" (Japan) around the world.

Origins:

Singapore Ants are native to India, Japan, Malaysia and Sri Lanka and are easily spread around the world through commerce and trade.

Known distribution:

Australasia-Pacific, North America, South America, Africa, Laysan, French Frigate Shoals, Hawai`i. In Hawai`i it is currently known to be established on Hawai`i, Kauai and Oahu

Biology:

Singapore Ant will nest in a variety of places but appear to be unable to establish themselves in undisturbed habitats such as forested areas. They are often found in urban areas as well as irrigated gardens, orchards, and rural areas. Singapore Ants spread quickly over long distances through human transportation of infested materials but will spread short distances through budding.

They forage on a variety of food sources from dead and live insects to sugary honeydew from plant sucking insects and nectar.

Impacts:

Singapore Ants are more of a pest in urban environments and as a house pest. Although they will forage on sugars and proteins the biggest problem is the destruction of electrical and phone lines. "Foragers gnaw holes in fabric and rubber goods, remove rubber insulation from electric and phone lines, and damage polyethylene cable" (Global Invasive Species Database). They can destroy or damage electrical lines in houses and cars which can lead to electrical fires.

BIG-HEADED ANTS

Scientific name:

The scientific name for the Big Headed Ant is Pheidole megacephala. It is also known as the "brown house-ant", "coastal brown-ant", "lion ant", and "Grosskopfameise" (German) in other parts of the world.

Origins:

The Big Headed Ant is believed to be native to southern Africa.

Known distribution:

It is widely distributed throughout the temperate sub-tropical and tropical regions of the world.

Biology:

Big Headed Ants get their name from the "major caste" of worker ants (often called soldiers) which have extremely large heads compared to the rest of their bodies. The smaller "minor caste" (small foraging ants) will forage on almost anything from sweet sugary liquids, dead insects, and plant seeds. They bring the food back to the nest where it is shared throughout the colony.

Colonies generally have multiple queens which can lay hundreds of eggs each day. The transportation of infested materials is known to distribute BHA over long distances, but they can also spread locally via budding and swarming depending on the climate.

The Big Headed Ant (BHA) can establish its self practically anywhere. Colonies may be found in agricultural areas, coastal areas, forest (natural and planted), wetlands, range/pastures, as well as urban/residential areas.

Impacts:

In rural areas, BHA are known to displace much of the native fauna through aggression and competition. They can directly impact crops through seed harvesting and indirectly by harboring plant sucking insects. BHA have also been known to chew through irrigation lines. They are a major pest of pineapples where they tend pineapple mealy-bug.

In urban/residential areas they often cause considerable damage to telephone and electrical lines in homes and buildings.

PENNANT ANTS

Scientific name:

The scientific name for the Pennant Ant is *Tetramorium bicarinatum*. It is also known as the "Bicolored Pennant Ant", "Guinea Ant", or "Penny Ant". The name Guinea Ant is also commonly used for a close relative *Tetramorium guineense*.

Origins:

The Pennant Ant is native to the Indo-Pacific region of the world.

Known distribution:

This is a cosmopolitan species commonly found around the world and is one of the most widespread species of ants globally. In Hawai`i it is most likely established on all of the major islands.

Biology:

Colonies of Pennant Ants are usually small to moderate in size and occur in urban environments, yards, gardens, green/shade houses. Nests can have multiple queens and workers can vary in color and size. It is believed that inseminated queens can found new colonies without the aid of worker ants. Pennant Ants are generalists in their diet and will feed on almost anything.

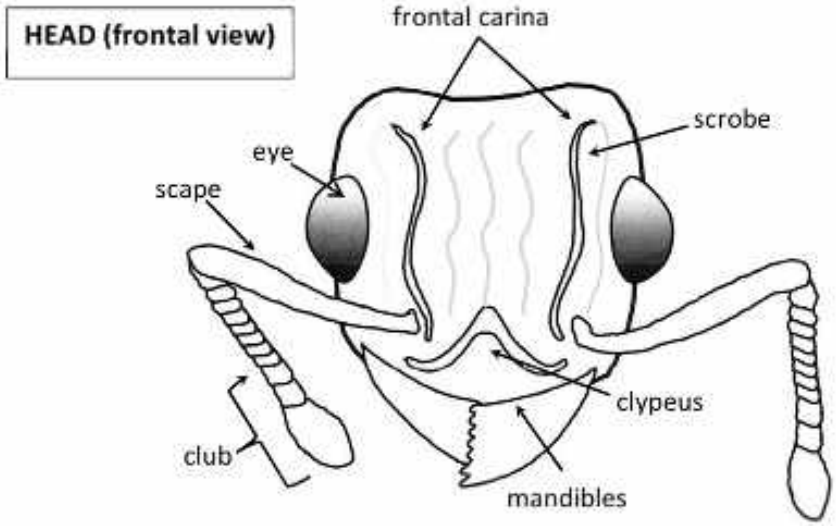
Impacts:

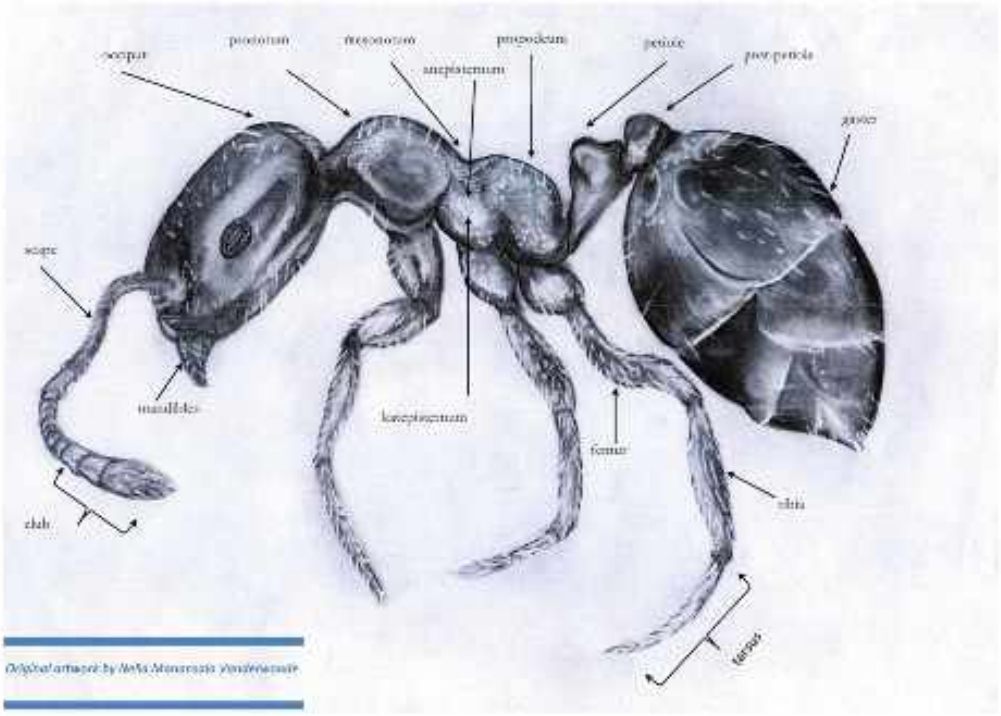
Although they are not considered to be a major pest, they can be a nuisance around the home and garden because of their ability to sting if provoked.

Glossary of Terminology

Antennal Scrobes –	a depressed area on the front of the head where the antenna lie when in rest
Anepisternum –	the area of the mesothorax
Appressed –	laying flat against the body (i.e. appressed setea)
Carina –	a ridge, usually long. Common on the head of an ant and marks where the antenna scape rests against the head
Clypeus –	the part of the face that is directly above the mandibles ("upper lip")
Clypeal Tooth –	a pointed projection(s) on the clypeus. May be difficult to see
Coxa –	the very first segment of the leg
Dorsal -	on the top surface
Dorsal view -	looking down, from above (opposite of ventral)
Frontal -	the view showing the "face" of the ant (opposite of posterior)
Gaster –	the "butt" of the ant
Mandibles –	the "jaws" of the ant
Mesonotum –	the middle part of the thorax
Metanoum –	the upper and front portion of the propodeum
Occiput (Occipital) –	the back of the head. Behind where the occeli are located on queen and reproductive ants
Petiole –	the waist of the ant. May consist of 1 or 2 segments or may be completely absent.
Posterior -	the rear, or the view from the rear (opposite of frontal)
Post-petiole –	the second segment of the waist (if present)
Profile view -	the view of an ant that shows the body, legs, gaster to the right and head to the left
Propodeum –	the rear section of the thorax where the petiole (waist) connects.
Propodeal Spines –	spines (usually 2) that arise from the rear of the thorax (propodeum)
Reticulate –	consisting of a network of veins that looks like a net or covered in fine bumps
Setae –	a thick, bristle-like hair
Scape –	the first segment of the antenna (long)
Suture –	a line made by the connecting of 2 or more exoskeletal plates such as the separation between the mesonotum and propodeum
Tarsus –	the segments of the leg that comes after the tibia
Tergites –	dorsal plate-like segments (i.e. gastral tergites)
Tibia –	3rd leg segment; segment after the femur
Thorax –	the "body" of the ant
Ventral -	on the underside
Ventral view -	looking from the bottom upwards (opposite of dorsal)

Morphological characteristics of an ant





Key to sub families of ants in Hawaii

(2018)

1 2-segmented petiole, very large bulging eyes (1a) ..... Pseudomyrmecinae (*Pseudomyrmex gracilis*)

2-segmented petiole (1b), eyes normal, reduced or absent ..... 5 Myrmicinae

1-segmented petiole or none apparent (1c)..... 2

2 profile of gaster without constriction (2a)..... 3

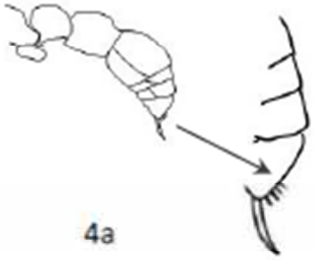
distinct weak constriction between 1st and 2nd gastral tergites, sting present (2b)..... 4

3 tip of gaster with a circular opening, often fringed with hairs (3a)..... 35 Formicinae

tip of gaster with a slit-like opening or no obvious opening, never fringed with hairs (3b) ..... 43 Dolichoderinae

4 last segment of gaster with a row of small spines along outer and trailing edge (4a);
gastral constriction strong giving the illusion of a 2 segmented petiole;
eyes absent ..... Dorylinae
(*Ooceraea biroi*)

last segment of gaster smooth in profile (4b)..... 50 Ponerinae



4a

4b

Myrmicinae

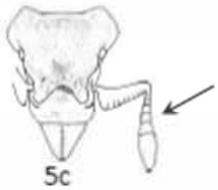
5 Antennal club 3-segmented (5a)..... 6

Antennal club 2-segmented (5b)..... 9

No distinct antennal club and/or with 6 antennal segments or less (5c) ..... 10 (*Strumigenys* spp.)

5a

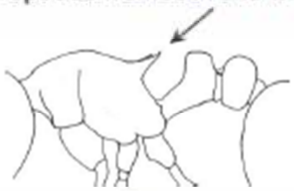
5b



5c

6 Propodeum with a distinct pair of spines (6a)..... 7

Propodeum smooth and without a spine (6b)..... 14 (*Monomorium* and allied spp.)



6a

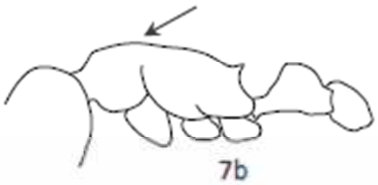
6b

7 Mesonotum with a deep and wide clef between the pronotum and propodeum;

pronotum rounded and clearly higher than propodeum (7a)..... 21 (*Pheidole* spp.)

Pronotum and propodeum on the same horizontal plane (7b)..... 8

7a



7b

8 Antennal scrobes present; front of the head between antenna sculpturing striate;

body sculpturing variable (8a)..... 23 (*Tetramorium* spp.)

Antennal scrobes absent, head and body sculpturing

not striate (8b)..... 27 (*Cardiocondyla* spp.)

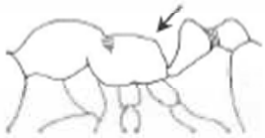
8a

8b

9 Propodeum with a distinct pair of spines (9a)..... *Wasmannia auropunctata*

Propodeum without spines (9b) ..... 31 (*Solenopsis* spp.)

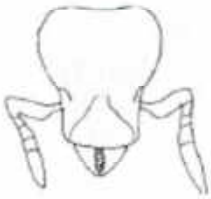
9a



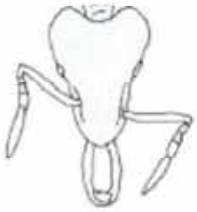
9b

10 Head heart-shaped, mandibles short (10a)..... *Strumigenys membranifera*

Head heart-shaped, elongated mandibles (10b)..... 11



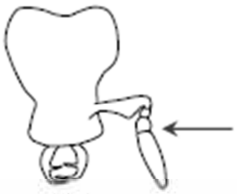
10a



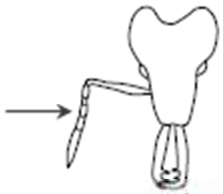
10b

11 Antenna (including the scape) composed of 4 segments (11a); head and dorsal surface of the body densely covered with large, bulbous, fan-shaped setae..... *Strumigenys emmae*

Antenna (including the scape) composed of 6 segments (11b); setae variable, may or may not be present..... 12



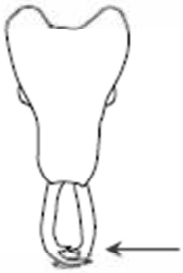
11a



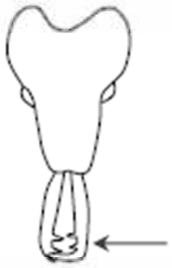
11b

12 Mandibles armed with 2 teeth; fan-shaped setae not present (12a)..... 13

Mandibles armed with 3 teeth; sparse, fan-shaped setae present on the front of the head (12b)..... *Strumigenys rogeri*



12a



12b

13 Pronotum covered with curved "woolly" non-erect hairs..... *Strumigenys godeffroyi*

Pronotum with sparse erect hairs..... *Strumigenys lewisi*

14 Head and thorax finely textured, giving a uniform dull appearance..... 15

Head and thorax smooth and shiny.....17

15 Head and thorax yellow or orange, or light brown..... 16

Head and thorax dark brown ..... *Monomorium indicum*

16 head, thorax and petiole with pairs of short stiff setae..... *Monomorium pharaonis*

Head and thorax with fine hairs (not erect)..... *Monomorium dichroum*

17 Head and gaster uniformly colored, both distinctly darker than thorax..... *Monomorium floricola*

Head not the same color as gaster (gaster may be bicolored) OR body uniformly colored.....18

18 Propodeum smoothly convex in profile (18a).....19

Propodeum with distinct dorsal and posterior planes (18b)..... 20

18a

18b

19 Head broadly rectangular in front profile, frontal portion of head hairless or nearly so (19a) ..... *Monomorium orientale*

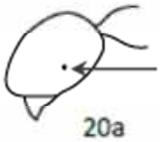
Head with pronounced occipital lobes in front profile, covered in long hairs (19b)..... *Monomorium liliuokalanii*

19a

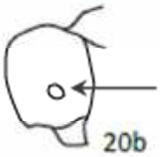
19b

20 Eyes very small, consisting of < 5 facets (20a)..... *Syllophopsis sechellense*

Eyes normal, with > 5 facets (20b)..... *Trichomyrmex destructor*



20a



20b

21 Head, and thorax finely sculptured giving a dull appearance (21a)..... *Pheidole navigans*

Head and thorax smooth and shiny in dorsal view (21b)..... 22

21a

21b

22 Minor caste: Post petiole with ventral bulge, region of face between antenna and eyes smooth and shiny, usually with mild or no sculpturing (22a) however, occasionally noticeable sculpturing is present; Major Caste: Head with striate sculpturing except for the occipital lobes which are smooth and shiny..... *Pheidole megacephala*

Minor caste: Post petiole never with a ventral bulge, region of face between antenna and eyes noticeably sculptured (22b); Major Caste: Head uniformly sculptured ..... *Pheidole fervens*

22a

22b

23 Petiole rounded in profile (23a)..... 24

Petiole blocky in profile (23b)..... 25

Top surface of petiole wave-like (23c)..... *Tetramorium insolens*

23a 23b 23c

24 Dorsal surface of entire body densely covered with long hairs; antennal scrobes smooth and shiny (24a) ..... *Tetramorium lanuginosum*

Dorsal surface of entire body with sparse long hairs (24b)..... *Tetramorium tonganum*

24a 24b

25 Large, total length > 3 mm ..... *Tetramorium bicarinatum*

Smaller, total length < 3 mm..... 26

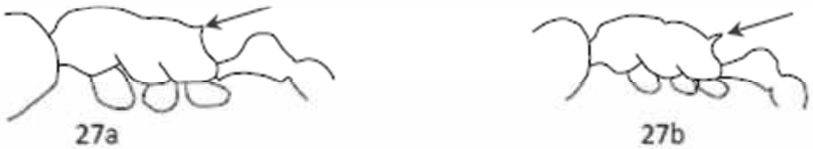
26 Antennal scrobes weakly defined, coarsely reticulated between and similar to the rest of the head when viewed from the profile(26a)..... *Tetramorium caldarium*

Antennal scrobes distinct, finely reticulated and contrasting from the rest of the head when viewed from the profile (26b)..... *Tetramorium simillimum*

26a 26b

27 Propodeal spine short in profile (27a)..... *Cardiocondyla kagutsuchi/venustula**

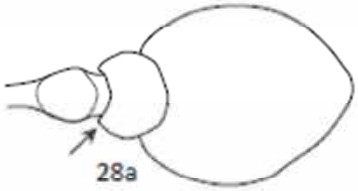
Propodeal spine moderate-long in profile (27b).....28



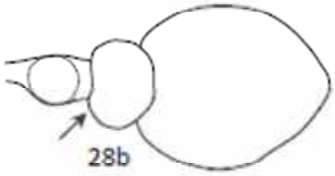
27a 27b

28 Anterolateral corners of post-petiole pointed in dorsal view (28a)..... 29

Anterolateral corners of post-petiole rounded in dorsal view (28b)..... 30



28a



28b

29 All gaster segments equally dark ..... *Cardiocondyla obscurior*

All gaster segments not equally dark, tergites with some color variation ..... *Cardiocondyla wroughtoni*

30 Dorsal profile of thorax interrupted by a distinct notch between the mesonotum and metanotum; ventral bulge present on the

postpetiole (30a)..... *Cardiocondyla emeryi*

Dorsal profile of thorax relatively smooth and without a notch between the mesonotum and metanotum; no ventral bulge present on the

postpetiole (30b)..... *Cardiocondyla minutior*

30a

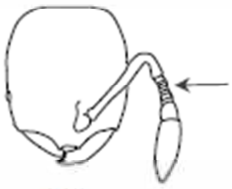
30b

31 Small, less than 2 mm; antennal segments between scape and club narrow,

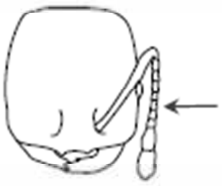
wider than high (31a).....33

Larger, > 2 mm; width of antennal segments between scape and club

the same as, or longer than wide (31b) 32



31a



31b

* Cardiocondyla kastuguchi and C. venustula must be separated via discriminant analysis on measurements of morphological features to reliably tell them apart. The two species have been grouped in this key.

32 Central clypeal tooth absent (32a); mandibles with three teeth or smooth (32b); lower portion of mesonotum often with a forward-facing tooth, Spine, or 'flap' (32c), majors with dis-proportionally large heads ..... *Solenopsis geminata*

Central clypeal tooth present (32d), mandibles with four teeth (32e), lower portion of mesonotum never with a forward-facing tooth or spine (32f) head of major workers proportionally the same size as in minors, ... *Solenopsis invicta*

(not present in Hawaii)

32a

32d

32b

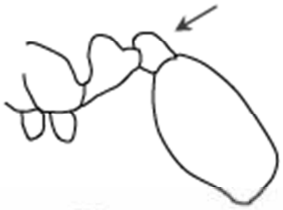
32e

32c

32f

33 Eyes reduced; post-petiole smaller than petiole (33a)..... 34

Eyes normal; post-petiole larger than petiole in profile view (33b)..... *Solenopsis globularia*



33a

33b

34 Body uniformly dark in color..... *Solenopsis papuana*

Body uniformly light ..... *Solenopsis* HI01

Formicinae

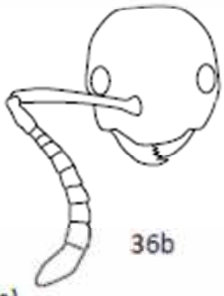
35 Small, total length <3 mm 36

Total length 3 mm or more..... 38

36 Body color brown, antenna consisting of 9 segments including the scape (36a).. *Brachymyrmex* sp. nr. *obscurior*

Body color yellow, antenna with 10 or more segments (36b)..... 37

36a

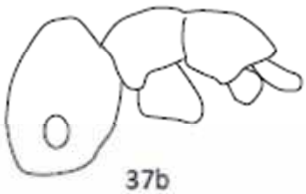


36b

37 Dorsal surface of thorax with pairs of erect setae (37a)..... 40

Dorsal surface of thorax without pairs of erect setae (37b)..... *Plagiolepis alluaudi*

37a



37b

38 Face in frontal view covered with thick hairs (38a)..... 39

Face in frontal view not covered with thick hairs

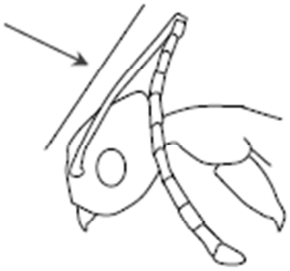
(38b, fine hairs may be present) 42

38a

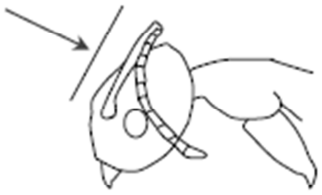
38b

39 Antennal scape long, more than 1.5 times the length of head (39a)..... 40

Antennal scape less than 1.5 times length of head (39b)..... 41



39a

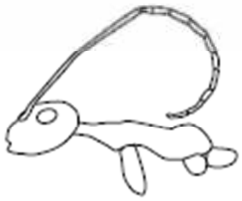


39b

40 Body covered with stiff black hairs; mesonotum narrow and with a steep slope, meeting the propodium at a wide angle in profile view; propodeum and petiole armed with blunt teeth (40a) ..... *Lepisiota* sp.

Body covered with stiff white hairs, mesonotum gradually sloping; propodium and petiole normal, not armed with teeth (40b)..... *Paratrechina longicornis*

40a



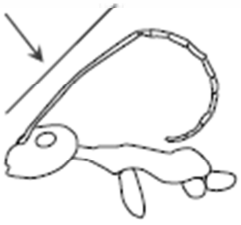
40b

41 Lower section of mesonotum with appressed setae ..... *Nylanderia bourbonica*

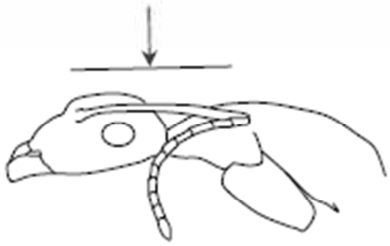
Lower section of mesonotum without setae, glabrous and shiny..... *Nylanderia vaga*

42 Antennal scape long, more than 2 times the length of head (42a)..... *Anoplolepis gracilipes*

Antennal scape less than 1.5 times the length of head (42b)..... *Camponotus variegatus*



42a



42b

Dolichoderinae

43 Rear face of propodeum distinctly concave (43a)..... *Ochetellus glaber*

Rear face of propodeum flat or convex (43b)..... 44

43a

43b

44 Petiole reduced or absent, forward face flat or indistinct (44a) 45

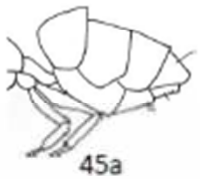
Petiole well defined, taller than wide (44b) ..... *Linepithema humile*

44a

44b

45 Gaster with 4 plates on the upper surface (5th tergite ventral) (45a)..... 46 (*Tapinoma* spp)

Gaster with 5 plates on the upper surface (45b).....47 (*Technomyrmex* spp)



45a

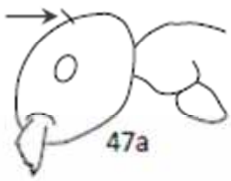
45b

46 Head and thorax distinctly darker than gaster..... *Tapinoma melanocephalum* complex

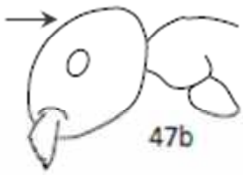
Head, thorax and gaster uniformly colored..... *Tapinoma sessile*

47 Occipital region of head above the eye with one or two erect setae (47a) this feature is best seen in profile view.....48

Occipital region of head without erect setae (47b) 49



47a



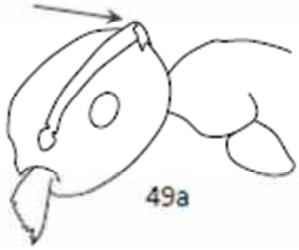
47b

48 Tarsus of hind leg lighter in color than tibia..... *Technomyrmex difficilis*

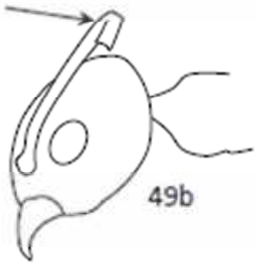
Tarsus of hind leg the same color as the tibia..... *Technomyrmex pallipes*

49 Scape short, extending to the rear margin of head when viewed in profile (49a).. ... *Technomyrmex albipes*

Scape longer, clearly extending beyond rear margin of head when viewed in profile (49b)..... *Technomyrmex vitiensis*



49a

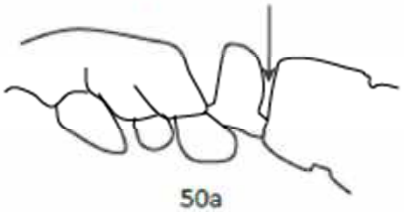


49b

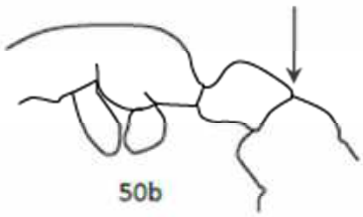
Ponerinae

50 Rear and front face of petiole distinct and well-defined (50a) 51

Rear face of petiole broadly attached to gaster (50b) ..... *Stigmatomma zwaluwenburgi*



50a



50b

51 Mandibles long and slender (51a & b) 52

Mandibles broadly triangular in frontal view (51c)..... 53

51a

51b

51c

52 Occipital lobes indistinct; mandibles long, slender, curved inward, and originating from the far lateral margins of the head (52a)..... ..... *Leptogenys falcigera*

Well defined occipital lobes present; mandibles long, straight, and not originating from the far lateral margins of the head (52b)..... *Odontomachus* nr. *ruginodis*

52a

52b

53 Legs and antennae distinctly lighter in color than head and thorax..... 54

Body, legs and antennae all the same color..... 55

54 Petiole roughly square when viewed in profile ..... *Platythyrea punctata*

Petiole much higher than wide when viewed in profile ..... *Hypoponera opaciceps*

55 Eyes completely absent..... *Hypoponera zwaluwenburgi*

Eyes small, consisting of a few facets..... 56

56 Ventral process of petiole with an acute angle (56a)..... *Ponera swezeyi*

Ventral process of petiole a simple lobe (56b) 57

56a

56b

57 Color yellow..... 58
Color brown..... 59

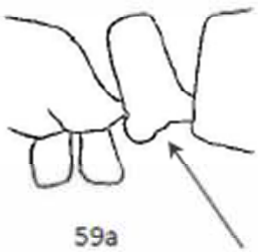
58 Mesonotum bisected by a distinct suture (anepisternal suture) in profile view, delineating the anepisternum from the rest of the mesonotum (58a) ..... *Hypoponera* HI01
Mesonotum without a distinct suture (58b)..... *Hypoponera ragusai*

58a

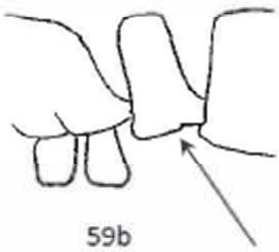
58b

59 Posterior margin of the ventral process on petiole highly skewed (59a)..... *Hypoponera opacior*

Posterior margin of the ventral process on petiole gradually sloping (59b)..... *Hypoponera punctatissima*



59a



59b

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