

5.0 PROPAGATING NATIVE PLANTS: INTRODUCTION



Growing your own plants for a restoration project is a highly rewarding endeavor. The other method to obtain plant material is through contract growing; hiring a commercial nursery to produce the needed plant material. Most native plants are fairly easy to grow from seeds or cuttings as long as a number of basic propagation methods are followed. This chapter highlights the various facets of nursery operations for restoration purposes. Content for this chapter is largely based on: *Native Forest Restoration: A Practical Guide for Landowners* (Porteous 1993). It has been adapted for Hawaiian restoration nurseries where appropriate.

5.1 SOURCES OF NATIVE PLANTS

Plant propagules (seeds, seedlings, and cuttings) for outplantings should come from the same local area as the restoration site for the following reasons:

- 1) **To ensure the maintenance of local gene pools and the use of locally evolved ecotypes.** In other words use species, subspecies, and varieties appropriate to a specific restoration area in order to restore the genetic health of a local community of native species. As an example the coastal ilima (*Sida fallax*) variety is not used in mesic forest restoration at Honouliuli Preserve because it is radically different in growth habit. Ilima at Honouliuli Preserve is presumably the same species, but unlike the coastal ilima which grows prostrate to the ground, in the preserve, ilima is a large shrub reaching heights in excess of 12 feet.
- 2) **To prevent the spread of plant diseases and insect pests.** The use of locally grown plant materials can help prevent the spread of highly destructive fungal, or viral pathogens, as well as insect pests on and between our islands. Koa (*Acacia koa*) wilt disease is spread by contaminated seeds. Ohia (*Metrosideros polymorpha*) rust is now spreading on Oahu and carried on leaves. A presumed papala kepau (*Pisonia umbellefira*) virus killed a number of large, mature trees on Oahu in a few short years. The number of new agricultural pathogens also grows every year. Restorationists should be part of the solution to forest loss, not part of

the problem by inadvertently transmitting plant diseases and insects from place to place.

5.1.1 COLLECTING WILD PLANTS

Plants for restoration are normally obtained by one of three methods: by seeds, cuttings, or seedlings. Collecting seeds and cuttings will be discussed in later sections of this chapter. One method of obtaining seedlings is to collect them directly from the wild. Several mesic tree species produce copious amounts of seedlings below the parent plant. Trails, roads, and fencelines slated for clearing are other areas where seedlings can be taken. If left alone, the majority of those seedlings would not survive due to self-thinning. These dense clusters of seedlings can be ‘salvaged’ and placed into pots for traditional container growing. Generally, the smaller the seedling is the better the success rate. Material should never be taken from protected areas such as National Parks or Natural Area Reserves.

- Seedlings about 1-5 cm generally have a good rate of transplanting success from the ground to a pot.
- When digging up the seedling it is helpful to make several angled cuts into the soil around the seedling. The goal is to take up as much of the soil surrounding the seedling’s roots in order to avoid transplant shock, in other words, the root ball should be left intact as much as possible.
- Seedlings should then be graded into size classes and the seedlings carefully transplanted into prepared and fertilized pots as soon as possible.
- Seedlings should not be left out in the sun, but rather shaded and protected from the wind until the roots have re-established themselves.
- It may also be helpful to trim one-third of the leaves of broad leaf tree species to minimize water loss.
- Since seedlings taken from the wild tend to have weaker root systems, they may take longer to grow to appropriate outplanting sizes. Further, the failure rate for transplanted seedlings upon final outplanting is likely to be higher than nursery grown stock given their weaker root systems. Nonetheless, this method can be used to supplement nursery grown material and is particularly useful for growing trees that are difficult or very slow to germinate.

The following tree species have been successfully outplanted at Honouliuli Preserve using wild seedling stock. Seedlings were collected at 2-5 cm in height and outplanted as 12 inch dibble, ½ gallon, or gallon sized pots. Plant heights at the time of outplanting varied from 5 cm to 50 cm. The majority of the seedlings were grown in field nurseries adjacent to outplanting areas. Survival rates are currently about 70%.

Acacia koa

Psydrax odorata

Pisonia umbellifera

Pisonia brunoniana

Myrsine lanaiensis seedlings will also be attempted soon.

Two smaller, endangered fern species (*Diellia unisora* and *Diellia falcata*) were successfully transplanted by the TNC-Oahu Program from wild sites threatened by landslides. Growing native ferns from spores is difficult and can take years to reach outplanting sizes.

5.1.2 CONTRACT GROWING

Besides growing plants oneself, hiring a grower instead can be just as cost-efficient. Reliable commercial growers will produce a set quantity of plants of a designated size at a known cost. The value of using a contract grower is that they have the facilities and knowledge to produce high quality plant material at a low unit cost. The more plants grown under contract the cheaper each plant will be. Community groups, individuals, or schools with similar plant material needs could consolidate orders to get a better price. Some important considerations regarding contract growing:

- Seed or cutting material should still come from the same local area as the restoration site. Seeds can either be given to the grower or the grower can be told where seeds can be collected.
- Nursery plants need to be properly labeled (species, source populations)
- Seed material must be collected and given to the grower well in advance (oftentimes 9-12 months or longer).
- Plants need to be delivered free of insect pests and other pathogens (including soil mealy bugs and nematodes).
- Plants still need to be hardened off. Plants grown for restoration will be subjected to many environmental extremes (heat, drought, wind storms etc.). Life in the wild is a far cry from the lush, heavily fertilized environments at most ornamental or landscape nurseries.

5.2 CONSTRUCTING A NURSERY



Propagating native plants is a lengthy process, but an integral part of revegetation efforts. One of the first essential steps in this process is constructing a nursery. The main requirements for a small nursery are:

- A convenient location with access to clean water
- A work area for seed sowing and potting.
- A cool, shady, moist area to germinate seeds and grow plants once they have been potted.
- An open, but sheltered area where plants can be placed to harden off before being planted.
- A storage area for pots, media, fertilizer, tools, and insecticide.

The facilities required will naturally depend on the scale of the nursery operation. While smaller numbers of plants can be grown in a domestic garden, larger production efforts require some sort of shade house to germinate seeds and establish small plants once they have been potted.

The area chosen as a nursery area should be sunny, sheltered, flat, and have both easy access and a reliable water supply. The location should preferably have the same rainfall and elevation as one's restoration sites. Although less accessible, nurseries established in the field are an attractive alternative. Field nurseries will be discussed in a Section 5.3.

5.2.1 WORK AREAS



Important work areas to plan for include a garden shed and a workbench. A garden shed is ideal for storing materials such as soil, fertilizers, and plant containers. A flat workbench is useful for sowing seeds, outplanting seedlings, and re-potting plants into larger containers.

5.2.2 SHADE HOUSES



A shade house or shade frame is essential for the germination of seeds and getting plants established once they have been potted into containers. Shade houses create their own microclimate, reducing evaporation, protecting against extremes of heat, wind, and sun, and reducing rain damage.

Shade houses can be small or very large. A shade house 15 x 15 ft or larger can easily be made from 'easy up' tent poles and shade cloth. Fifty percent shade cloth is the most common material used. However, if multiple shade houses are built, the use of different gradients of shade cloth may be beneficial. A darker shade house (70% shade) for germinating plants, and a shade house with 50% shade cloth for hardening plants are used by the TNC-Oahu Program. Some growers prefer to keep the ends of their shade houses open (non-enclosed) for maximum air circulation.

5.2.3 HARDENING OFF AREAS



After establishing themselves in their containers plants are then placed out in an area to “harden off.” This important stage allows the plant to develop more woody tissue (lignification), deeper and more developed root systems, and thicker leaf cuticles in order to be more robust and ready to withstand the natural conditions of a forest. Higher light levels also help plants reach maturity and reproduction.

Weed control is necessary in the hardening off area and shade houses. This can be done by:

- a) Using herbicides to kill existing weeds and then laying polythene sheeting and gravel. The polythene sheeting is laid over the site and a layer of gravel chips less than a half inch thick is spread on that to a depth of about 2 in.
- b) Laying a weed control mat. Although more expensive than the above, this strong, woven polypropylene fabric allows water to seep through and air to escape, and is also stabilized against ultra-violet light. Water seepage prevents standing puddles of water (which often occur when sheet plastic films are used), minimizing bacteria, algae, and fungal problems. For best results, the ground should be leveled and covered with gravel before installation.

5.2.4 QUARANTINE AREAS

For larger scale nurseries, a quarantine area can be helpful in isolating pest problems. As new plants are brought in or conversely, being readied for outplanting, they can be placed in the quarantine area to ensure that further contamination does not occur. The quarantine area can be attached to an existing shadehouse as long as some kind of sufficient barrier exists to block the spread of insects and pathogens.

5.2.4 FIELD NURSERIES



Pisonia sp. seedlings on automatic drip tube irrigation

Field nurseries established at the margins of an existing forest remnant or adjacent to restoration sites can provide favorable conditions for the propagation of native plants. At Honouliuli Preserve and at Haleakala National Park, field nurseries produce large amounts of common and endangered plants with minimal upkeep. Automatic timer

irrigation systems are attached to water storage tanks which are set beneath a water catchment system. Seedlings are either brought in from the wild or from traditional nurseries. Seeds are also started on regular nursery benches. Media can be surrounding forest soil or standard nursery mixes brought in by foot or helicopter. Field nurseries have several benefits despite being less accessible:

- Plants are exposed to the same climate and insect environment as the restoration site where they will be used.
- Travel expenses of bringing plants in by foot or helicopter are greatly reduced if not eliminated.
- There is far less risk of bringing in new insect pests or pathogens to restoration areas.

5.4 PROPAGATION OF NATIVE PLANTS FROM SEEDS

Propagation from seed is the easiest and most commonly used method of propagating native trees and shrubs. It is also preferable to propagating from cuttings, as propagation by seed produces greater genetic diversity. Appendix 5A is an example of a plant production calendar used to ensure adequate nursery plant material is available for planting. For detailed and comprehensive instructions on the collection, handling, and storage of seeds from native Hawaiian plants, please see the excellent on line manual, *Seed Storage Practices for Native Hawaiian Plants* available at:

www.hawaii.edu/scb/docs/science/seed/seedmanual.html or through the Hawaii Conservation Alliance website. It was produced by Alvin Yoshinaga of Lyon Arboretum and the University of Hawaii's Center for Conservation, Research and Training. The table of storage properties for specific native plant species continues to be updated. The following considerations are intended to provide a cursory highlight of some of the information contained in the above mentioned seed storage manual.

5.4.1 SEED COLLECTION AND TRANSPORT



Photo by Amy Tsuneyoshi

Seed collection times will vary even within local areas from year to year. From the time of flowering and on, plants intended to be collected from should be closely monitored. Creating a flowering and fruiting calendar for native species in your area is an invaluable

aid to seed collection. Also, make sure all necessary permits to collect that seed are obtained well in advance.

A common problem is the lack of sufficient quantities of seed for larger restoration efforts. Using planter boxes for growing seed stock or row crop farming are two strategies commonly used to generate large quantities of native plant seeds for restoration purposes.



Seeds must be mature and healthy when stored, otherwise their germination rate will be poor, their seedlings will have poor vigor, and their storage life will be short. Collect mature seeds from healthy plants. As with store bought produce, some seeds, if collected immature, can be ripened by storing the fruits in a cool, well-ventilated place. A ripe apple giving off ethylene gas can also be placed with the undeveloped fruits to assist in maturation.

Seed can be stripped or picked off lower branches of trees and shrubs, or collected off the ground. Where seed is prolific and the relevant permission is obtained, small branches can be pruned off for stripping at a later time. Where seed is out of reach, shade cloth sheets can be laid on the ground or suspended above the ground (to deter rodents) during seed fall. If seed is light and easily dispersed by the wind, it is best to collect seed capsules shortly before they open. Seed can also be raked up with forest litter.

In general, procedures for transport of seeds are similar to those for fresh produce. Seeds should not be exposed to high temperatures. Avoid leaving storage containers in the sun or inside closed vehicles. Seeds need to be packed loosely and be well ventilated. For example, if the seeds are kept in plastic bags, the bags should be open to allow air circulation.

5.4.2 SEED CLEANING

Before sowing or storing seed for sowing later, some seeds must be cleaned to remove material such as fleshy fruit and seed husks. The following most common seed cleaning techniques for a number of mesic native trees, shrubs, sedges, and grasses are listed below.

SOAKING: Briefly immersing seeds in water will help to initially sort out the viable and nonviable seeds. Good seeds will generally sink while the nonviable seeds, as well as debris, will float to the top and can be discarded. Species that have fleshy pulp surrounding the seeds should be soaked in clean, cool water from 2-24 hours depending on the species. This technique aids in softening the pulp, making the seeds easier to remove. Fungicide or diluted bleach solution (5 %) may be added to the water to keep seeds viable.

PUREE: If large amounts of fleshy fruits with tiny seeds are collected (e.g. *Pipturus albidus*), a small food processor or blender can quickly puree the fruits. The mixture can then be more readily strained through cheesecloth to remove excess water in preparation for drying.

DRYING: Once seeds are largely separated from the pulp, they can be dried in a low humidity area or by using silica. Avoid using heat to dry seeds. See the above mentioned seed storage manual for a discussion on drying seeds.

FRICTION: Rub the fruit together to break away husks and separate out the seeds. Winnowing can also assist in removing chaff.

SIEVES: Once the fruit has been soaked or rubbed to remove fleshy or dry matter, it is put through a sieve to separate out the seeds from husk material.

SAND: Sterile sand is added to fruit with sticky or very tiny seeds to help separate them and make sowing easier.

5.4.3 SEED TREATMENT

Special treatment of seeds can speed up germination in some species and/or improve the rate of germination in others. There are several main types of seed treatments:

- mechanical scarification
- acid scarification
- heat treatment and
- cold treatment (stratification).

5.4.4.1 MECHANICAL SCARIFICATION

Many seeds have a hard protective coat that prevents the entry of moisture essential for germination. These seeds can be treated by manually cutting the seed coat, soaking the seeds in hot water, or subjecting seeds to a flame, causing their seed coats to crack.

The hard outer seed coat can be broken manually by:

- Nicking the outer coat with a nail clipper (dog nail clippers work best for larger seeds).
- Scraping it with a file or on sandpaper.
- Placing the seeds with other coarse material such as cinder and shaking the mixture. A motorized rock tumbler might also work for larger seeds.

It is important to not remove the entire seed coat; rather the goal is to simply create a small breach in the seed coat barrier, just enough to allow water in. It is also important to preserve the integrity of the embryo. This can be done by making the cut on the side opposite the embryo. Before the entire batch of seeds is nicked, a few seeds may be cut open to determine the location of the embryo. Note that this technique is most practical for plants with small seed lots as the process is very time consuming.

5.4.4.2 HEAT SCARIFICATION

The easier and more common method of scarification uses hot water, and varies based on the degree of treatment necessary. Some techniques are listed below:

- Heat about ten times the volume of water as the volume of seed to be treated, so that the water does not cool too quickly while the seeds are soaking. Remove boiling water from heat to cool slightly. Pour water over seeds and let sit anywhere from 30 seconds to several days before sowing.
- Briefly immerse the seeds in boiling water for various durations depending on the species, then transfer to cold water. Placing the seeds in a mesh bag makes these treatments easier to do. Experiments can determine the optimum immersion time, thirty seconds is a good time to start with.

Flaming seeds can be done by passing seeds through flames using a gas burner or immersing seeds in burning rubbing alcohol for brief periods. Seeds from the Malvaceae family typically respond well to a few seconds of flaming.

5.4.5 LABELING

All seeds need to be properly labeled and identified when stored or transported. Labels may include the following:

- Name of species
- Location seed was collected
- Environmental factors such as rainfall, temperature, range, and elevation
- Number and health of plants collected from
- Date
- Collector's name
- Seed lot number

- Any scarification, drying techniques before storage
- Seed cleaning method including any insecticidal or fungicidal treatments
- Recommended seed storage method

5.4.6 SEED STORAGE

Given the number of issues associated with the storage of native species, readers are referred again to the online manual “Seed Storage Practices for Native Hawaiian Plants” produced by Alvin Yoshinaga.

5.5 SOWING SEED



Seed germinating soil can also be purchased in bags from landscaping and garden supply stores, or it can be made up using equal ratios of soil, fine cinder, and fine perlite. Alternatively, mixtures of sand and peat in varying proportions can be used, as well as other materials such as vermiculite for more water retention. Fertilizers containing micronutrients (e.g Apex™ or Micromax™) should also be added to the seed starting media. Seed media should be well moistened prior to planting seeds. Beware that homemade dirt soil mixes, unless sterilized, may contain weed seeds, nematodes, and fungi harmful to germinating seeds and restoration sites.

Mycorrhizal inoculated soil from naturally occurring native plant populations can significantly assist plant growth. A website containing instructions for making your own mycorrhizal inoculated soil is give at the end of this chapter.

Seeds should be treated (scarified, soaked, sterilized etc.) prior to sowing. For tiny seeds or seeds that are sticky, sterile sand may be added to make handling of seeds easier and to avoid sowing too many seeds in one pot.

5.6 SOWING IN CONTAINERS



Containers suitable for sowing seed include: plastic seed trays (available from horticultural suppliers and some nurseries), 1-2" pots, dibble tubes (shown above) and many household plastic containers. These containers should have good drainage, hold the germinating medium, and be easy to handle.

Fill the seed sowing container with soil mix, then smooth and press down the material. Keep seed distribution as even as possible. The use of 1" plug seed flats or dibble tubes are very helpful in keeping seeds separated and assisting with transplanting after initial growth. Seed flats (shown above) are useful for seeds with very staggered germination times. Fine seeds should be firmly pressed down into the media to ensure good seed to soil contact. Other seeds are firmed down in a similar manner, then covered with media to their own depth and lightly pressed down. A common mistake is to bury seeds too deeply. Tiny seeds need only be scattered on the top of the soil and gently pressed into the media with a flat surface. Larger seeds should only be buried no more than the width of the seed itself.

After sowing, moisten the seed media again by misting it with a fine spray of water or place the container in a tray of water, allowing the media to soak up the water. Containers should then be placed in indirect light, not direct sunlight to avoid drying out and excessive heat. The seed trays should never be allowed to dry out, but rather kept moist for optimum germination rates. Spray as needed with fungicide, algacides, and insecticides to prevent disease and insect problems which kill young seedlings.

In cooler, higher elevation climates, the temperatures of the seed flats can be raised by a variety of methods. Commercially available warming trays placed under the flats are a somewhat expensive method. An alternative, cheaper method is to place plexi-glass over the flats and covering the plexi-sheets with newspaper. As soon as germination begins, the covers and newspaper should be removed.

5.7 CONTAINER SOWING USING COMPANION PLANTING TECHNIQUES

Companion planting, or growing plants together in the same container in the nursery, has proven successful for some native Hawaiian plants (Garnett 2003). In fact, certain combinations of species planted together have shown to be more successful when grown together than when grown separately. One such example is *Acacia koa*, when co-planted with *Bidens*.

To do this, sow koa seeds 4 in. deep into a “dibble tube” (SC-10 Super Cell; 1.5 in. diameter, 8 in deep; Stuewe & Sons Inc.), then either transplant a *Bidens* or direct sow their seeds on the substrate surface. As the shrub grows, it binds the container substrate, and after outplanting the koa seeds eventually sprout and establish. In addition, the fast growing *Bidens* provide a seed source on site within a year, which can be allowed to fall and sprout in place, be harvested and scattered on another site, or be harvested and returned to the nursery to propagate more plants (Garnett 2003).

5.8 TRANSPLANTING SEEDLINGS AND LARGER PLANTS

MATERIALS NEEDED FOR TRANSPLANTING:

- Clean pots (for seedlings, 1-2” pots; for bigger plants, one size bigger than pots which plants are already in)
- Moist media (mixture depends on plant)
- sterile cinder to place at the bottom of pots for drainage (optional)
- Plant tags & pencils
- Small digging tools
- Plant trays for organizing & carrying large numbers of small pots
- Liquid fertilizer or transplanting hormone (optional)

5.8.1 WHEN TO TRANSPLANT

For seedlings, transplant after the first 2-4 true leaves appear. For older plants, transplant before the plant outgrows the pot. This can be a subjective judgment, but generally if you check the bottom of the pot and can see roots in the drain holes, the plant is ready to transplant. Ideally, the plant should be transplanted just as roots are reaching the bottom of the pot to avoid root coiling.

5.8.2 MEDIA

Media will depend on the plant species, but generally a well drained media is highly recommended. If available, place washed larger rocks, clean gravel, or sterile cinder at the bottom of pots to prevent soil from leaking out the drain holes and to improve air circulation to the roots. Rocks at the bottom will however make pots heavier and more difficult to transport.

Prepare the soil mixture for your transplants by mixing and wetting the media until all parts are moistened. An equal ratio of perlite, cinder and sterile peat soil is a good general mix. Perlite (also called sponge rock is simply cinder exploded like popcorn by putting it under high pressure). Vermiculite and more peat can be added for plants that like wetter soils.

A balanced fertilizer with micronutrients should also be well mixed into the media. Even distribution of fertilizer is often difficult when mixing large batches of soil. A cement mixer is very helpful for larger batches of transplanting media. Otherwise, mix smaller batches of media (e.g. one wheelbarrow full).

5.8.3 TRANSPLANTING SEEDLINGS

Again, transplant when the first 2-4 true leaves appear. Pick a shaded area to work and have all supplies ready (pots, moist media, digging tools, plant tags etc).

With a small flat tool (Swiss army blade, tongue depressor, chopsticks etc), gently lift seedling out of the media by carefully digging underneath it. Avoiding damaging root hairs as much as possible. If need be lift seedling only by the leaves as the stem is very fragile.

Plant seedlings in 2 or 3 inch pots. Do not place seedlings in too large a pot as the root system is too small to take up that much water and the seedling will rot.

Avoid coiling roots at the bottom of pots. Place a small amount of moist soil at the bottom of pots, and hold seedlings in the middle of the pot. Again, for small seedlings, hold leaves, not the stem. Place soil around roots while holding the seedling up. Bury seedling up to original soil level with moist soil. Perlite can also be placed on top of the soil if damping off is a problem. Damping off is a fungus which attacks seedlings that are in media that remains too wet. Place seedlings back in the shade. Gently rinse any dirt off the leaves.

5.8.4 FERTILIZING SEEDLINGS

If fertilizer was not mixed into the media already at the time of transplanting, after about 2-3 weeks after transplanting when roots have 'reset' themselves, small amounts of slow release fertilizer with micronutrients can be added as top dressing, but liquid fertilizer is usually best at this stage.

5.8.5 DEALING WITH SEEDLINGS ROOTED TOGETHER

Either gently pull seedlings apart if not too stuck or if seedlings are really rooted together simply pinch one stem to kill one of the seedlings. Pinching stems can also be done in the tray before transplanting to thin weak looking seedlings out.

5.8.6 TRANSPLANTING BIGGER PLANTS

Again, see if roots are beginning to appear by the drain holes. Have transplanting materials ready. Pick pots only one size larger than original pots. For example, plants in 4 in. pots can be transplanted to 1 gallon 6 in. pots. Transplanting into too large a pot (over potting) will not save time as the plant's roots cannot take up all the water in the pot and eventually the roots may rot. Partially drying out the soil in the plants to be transplanted often makes it easier to get the plant out in one mass of soil and roots.

Moisten transplanting media by soaking pots half filled with soil in a full sink or by wetting mixed media in a wheelbarrow. Place some cinder or gravel in the bottom for drainage.

To extract plants from the pots, gently squeeze the sides to loosen soil. Place hand on top of the soil with fingers around the stem. Turn pot over carefully, making sure the top of the plant does not break against any surface. If the plant does not slide out, gently spank the bottom of the pot to free it. Do not pull on the stem to take plants out as this breaks surface roots that do much of the water and nutrient uptake. A chopstick can also be inserted into the drain holes to push plants out from the bottom.

Keeping as much of the root ball intact, place in center of new pot and place soil around plant, reburying it at the original soil level. Burying it too deep will rot the stem. Burying it too shallow will expose surface roots over time.

Top dress with slow release fertilizer or liquid fertilizer to avoid transplant shock for delicate species (these tend to be ferns and other high water demanding herbaceous plants). Placing plants in the shade will also help alleviate transplant shock.

5.8.6.1 DEALING WITH COILED OR MATTED ROOTS

Unless you're transplanting bonsai plants, cutting roots is generally a bad idea as it often does more damage than good. Gently tugging apart roots is fine but remember that uptake of water and nutrients happens by diffusion across very fine root hairs, the ones most easily damaged by handling, resulting in plant "shock". Plants will eventually explore new soil areas given time.

5.8.6.2 DEALING WITH PLANTS STUCK IN THEIR POT OR POTS TOO BIG TO LIFT

Carefully use a sharp knife or scissors to cut the pot and/or break the pot apart to take the plant out. Avoid pulling hard on the stem as it damages the roots. Rolling pots under pressure may also help to free plants.

5.8.7 CONTAINER GROWING

Commercial potting mixes or a mix of $\frac{1}{3}$ Sunshine # 4 peat soil, $\frac{1}{3}$ cinder, and $\frac{1}{3}$ perlite can be used. Slow release fertilizer should also be mixed into the potting mix.



Root trainers pots (a.k.a. book pots) are commonly used for tree and shrub species. They are sheet plastic containers in sets of four or more, hinged along the bottom. The sides are spread apart to lift out the plant for planting. The individual containers have vertical grooves to discourage spiral growth of the root system. The containers fit into a wire basket and are held off the ground, which air prunes roots as they emerge at the bottom of the container. Normally, seeds are directly sown into the root trainers and excess seedlings are pinched off.

Tree pots of various sizes or dibble tubes are commonly used for trees (tree pots are available from Stuewe & Sons Inc.). The vertical grooves similarly train roots down and the large drainage holes at the bottom assist in aeration. Tree pots need to fit into wire mesh racks or crates to keep them upright. Dibble tubes of various sizes are placed into dibble tube racks. Dibble tubes are also very useful for growing large quantities of 'plugs' for grass species.

5.8.8 PROPAGATING PLANTS IN THE OPEN GROUND

Unlike plants grown in a container, plants grown in the open ground have no restriction on root growth, and when the plants are lifted out of the ground for transport to the planting site, the roots often have little or no soil around them.

Seedlings or cuttings can be transplanted into prepared beds, or alternatively, seed can be sown directly into the beds. Use a rake to cultivate the top 2 inches prior to seed sowing. The seeds can be sown in rows or broadcast over the whole bed. After sowing, moisten the seedbeds and place fifty percent shade cloth over the seedbeds to help retain moisture, increase humidity, and exclude rodents, birds, and cats (Porteous 1993).

Because of nematode problems throughout Hawaiian low-elevation agricultural and urban areas, propagating plants in the open ground is not suitable for restoration sites free of nematodes. However, The Nature Conservancy-Oahu Program has had some success using planting beds underneath their field nursery tables in order to acquire additional seedling stock and maximize scarce water supplies.

Once the seedlings have germinated, they can be lifted out into containers or planted in restoration sites directly.

5.8.9 PROPAGATION OF NATIVE PLANTS FROM CUTTINGS

Many trees and shrubs can be raised from cuttings. In taking cuttings, note the following:

- Take cuttings from a range of plants to ensure greater genetic variation.
- Always take cuttings from healthy plants.
- Short side shoots should be used rather than rapidly growing terminal shoots.
- Always use a clean, sharp knife or clippers to avoid damage to stems.
- Keep cuttings cool and moist at all times during preparation.
- Keep detailed records of all aspects of the process and results.

5.8.9.1 SOFTWOOD CUTTINGS

Cuttings are a useful propagation method when large quantities of plant stem material is available. Species which naturally root at multiple nodes (e.g. vines) are especially useful. Cutting ‘slips’ are made by cutting apart material about 9-12 inches long. Cutting material should be treated similarly to cut flowers. As cutting slips are made, they should be placed into a bucket of water to minimize water loss and prevent an air bubble forming at the cut end which prevents water uptake. Lower leaves are stripped or cut off and upper leaves are commonly trimmed to a third of their original size to minimize water loss. Slips can be placed into rooting hormone as needed and placed into prepared flats or containers with at least a 1/3 to a half of the stem inserted into the media. For species with multiple stem nodes, insert at least two nodes below the surface of the media. Because cuttings have no root system, they should be placed in the shade and under an automated misting system to ensure rooting. Full rooting can be determined by gently tugging on stems. The more resistance is felt, the stronger the root system. Any cuttings which do not take (i.e. just rot and not root) need to be removed to prevent fungal contamination of remaining stock.

The root systems of plants generated from cuttings are generally not as healthy and extensive as plants grown from seed. Exceptions include certain vines and grasses grown from split culms. Of course, the longer plants are allowed to grow in containers, the larger their roots masses become.

5.9 NURSERY PEST MANAGEMENT

As with weeds, early detection and quick response is the best approach for effectively controlling nursery pests. A nursery should be inspected at least once a week to determine if new infestations occurred. See **Appendix 5C** for a Phytosanitation and Standards Guidelines adapted from the Makua Implementation Plan for detailed instructions on managing common nursery pests. **Appendix 5D** contains a table of the most commonly used pesticides in nursery operations.

5.9.1 REFERENCES

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Appendix 5A: Production Calendar																	
FY05-FY06 PRODUCTION SCHEDULE: COMMON NATIVES																	
GROWING PERIOD														PLANTING PERIOD			
TREES:	GOAL	POT SIZE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
ACAKOA	3000	DIBBLES															
PISBRU	1500	DIBBLES															
PISUMB	1000	DIBBLES															
PIPALB	1000	DIBBLES															
LABKAA	200	1/2 G															
UREGLA	50	1/2 G															
CHAOBO	200	1/2 G															
METPOL	200	1/2 G															
POUSAN	72	1 G															
TETOAH	72	1/2 G															
PITGLA	200	1/2 G															
MYRLAN	200	1/2 G															
MYOSAN	72	1/2 G															
PSYHAT	100	1/2 G															
PYSODO	72	1/2 G															

SHRUBS:	GOAL	POT SIZE	GROWING PERIOD										PLANTING PERIOD				
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
DODVIS	400	BOOK POTS															
HEDTER	150	1/2 G															
DIASAN	400	BOOK POTS															
BIDTOR	400	BOOK POTS															
COPFOL	100	1/2 G															
SIDFAL	160	BOOK POTS															
COVER:	GOAL	POT SIZE															
PLUZEY	400	BOOK POTS															
CARWAH	400	BOOK POTS															

Appendix 5B: Propagation and Outplanting Information for Common Mesic Native Hawaiian Plants

SCIENTIFIC NAME	HAWN NAME	TYPE	SEED	POT SIZE	NURS PERIOD (mos.)	GERMIN / GROWTH RATE	PRIORITY/ FIELD NURSERY	COMMENTS
CANOPY								
<i>Acacia koa</i>	koa	C	O	1 gallon tall Dibble tubes 4 inch	9 5 5	fast/fast	high/YES	Sow seeds in book pots after hot water soak, re-sow non-germinations. Harden off to stimulate phyllodes. Responds well to fertilizer and/or mycorrhizal inoculated soil. More info available at <u>http://pdcs.ctahr.hawaii.edu:591/hawnprop/</u>
<i>Charpentiera obovata</i>	papala	C/U		1/2 gallon tall	9	moderate/fast	high/YES	Moderate, staggered, germination rates (up to 4 months) for older stored seed. Fresh seed germinates in 3-4 weeks after overnight soak. Rapid growth after 6 inches high. Recommend continued outplanting 1/2 gallon. Smaller plants susceptible to lethal predation from native borer bug: <i>Mapsidius charpentieri</i> .
<i>Dodonaea viscosa</i>	aalii	C/U		Book pots 4 inch	9	fast / fast	high/YES	Quick germination if hot water soaked. Sow directly in book pots given tap root. Pest resistant, but prone to powdery mildew, scales. Tolerates light shade to full sun. Spray with fungicide to reduce mildew, but only after they are established in 4 inch pot. Field stock is better for seed collecting. More info available at <u>http://pdcs.ctahr.hawaii.edu:591/hawnprop/</u>
<i>Metrosideros polymorpha</i>	ohia	C	O	1 gallon tall	12	slow/slow	high/YES	Slow germination (2 mos.). Sow directly in dibble tubes and pinch weaklings. Prone to aphids and root mealy bugs. Shade to full sun. Fertilizer will significantly increase growth rates. Recommend outplanting at 1 gallon tall boy for maximum survival. More info available at <u>http://pdcs.ctahr.hawaii.edu:591/hawnprop/</u>
<i>Myrsine lanaiensis</i> <i>M. lessertiana</i>	kolea	C	R	1 gallon tall	11	slow/slow	med/YES	Slow germination. Shade to full sun. Slow growing in nursery, faster once outplanted. Recommend outplanting at 1 gallon tall for maximum survival.
<i>Pisonia brunoniana</i> <i>P. umbellifera</i>	papala kepau	C		1/2 gallon Book pots	9 5	fast/fast	high/YES	Quick germination if seeds excised from "fruit" or ends snipped. Sow directly in dibble tubes or book pots. Seeds will rot if heavily watered. Shade to partial sun. Prone to aphids and root mealy bugs. Grows slowly in wild. Recommend outplanting at 1/2 gallon or book pots in very large numbers.
<i>Pittosporum glabrum</i>	hoawa	C		1/2 gallon short	16	slow/fast	med/YES	Research needed on breaking dormancy of seeds. Can be 12 months before germination and then all at once. Plants tolerate drying down of soil in pots, fairly pest resistant. Rapid growth once planted in ground.
<i>Pouteria sandwicensis</i>	alaa	C		1/2 gallon short	12	moderate/slow	low	Seeds prone to rotting if heavily watered. Slow growing seedlings, faster after 6 inches. Staggered germination, sow in large quantities for sufficient plant material.
<i>Psychotia hathewayi</i>	kopiko	C		1/2 gallon short	12	moderate/slow	med/YES	Germination in about 3-4 months, seedlings grow very slowly at first. Fairly pest resistant. Does not like heavy watering.
<i>Psydrax odorata</i>	alahee	C		1/2 gallon short	12	slow/slow	low	Easier to collect seedlings below garden trees than attempting to germinate from seed. Fairly pest resistant. Suitable more for dry-mesic forest areas
<i>Sapindus oahuensis</i>	lonomea	C		1 gallon tall	12	moderate/slow	low	Faster germination if you remove exocarp (see Koebele / Culliney book). Very sensitive to brown mites. Low priority given slow growth and sensitivity of nursery grown trees to water stress. Recommend outplanting at 1 gallon tall boy size. More info available at <u>http://pdcs.ctahr.hawaii.edu:591/hawnprop/</u>
<i>Tetraplasandra oahuensis</i>	ohe mauka	C		1/2 gallon short	12	moderate/slow	low	Viable seed will germinate in large numbers. Fairly pest resistant. Seeds may require dormancy period for germination characteristic of Araliaceae species.

Appendix 5B: Propagation and Outplanting Information for Common Mesic Native Hawaiian Plants

SCIENTIFIC NAME	HAWN NAME	TYPE	SEED	POT SIZE	NURS PERIOD (mos.)	GERMIN / GROWTH RATE	PRIORITY/ FIELD NURSERY	COMMENTS
UNDERSTORY								
<i>Bidens torta</i>	kookoolau	U	O	book pots 4 inch	6 6	fast/fast	high/YES	Rapid germination (1 mo.), growth, maturation (12 mos. for seed set), and tolerance for range of environmental conditions (light shade - sun) make kookoolau one of the best understory restoration species. Does not tolerate heavy shade. Recommend direct seeding in the field when large numbers of fruit are available as well as in book pots. Outplant at book pot or 4 inch size.
<i>Chenopodium oahuense</i>	aweoweo	U		Dibbles 4 inch	4	fast / fast	low	Sow directly in book pots or 4 inch pots. Low priority for current mesic / wet restoration sites (because it is a dry forest / shrubland species). Recommend direct sowing in full sun, erosion prone areas for quick cover.
<i>Cyanea angustifolia</i>	haha	U		1/2 gallon	12?	fast/slower	low	Quick germination, but slow growth at seedling stage. Sow directly in dibbles or book pots. Faster growth after outplanting. Experiment with adding native myco soil for speed. De-seed fruit in a solution of 1/150 bleach and water, which helps seeds sink to the bottom of the container (otherwise seeds may float on surface due to water tension and be difficult to separate from pulp. Both nursery stock or field stock is good for collecting seeds. Once common understory species, low priority for propagation given pest problems.
<i>Hedyotis terminalis</i>	manono	U	O	1/2 gallon short Book pot	12 9	moderate/fast	high/YES	Moderate germination (1 month) if fruits soaked in water overnight. Sow directly in dibble tubes and pinch weaklings. Prone to aphids and root mealy bugs. Tolerates shade to full sun. Does not like heavy watering. Recommend outplanting at 1/2 gallon short boy or book pots.
<i>Urera glabra</i>	opuhe	U		1/2 gallon short	12	moderate/slow	low	Dioecious plant, not all seeds viable. Specialty species used for host plant for ground snails. Experiment with cuttings for faster propagation.

Appendix 5B: Propagation and Outplanting Information for Common Mesic Native Hawaiian Plants

SCIENTIFIC NAME	HAWN NAME	TYPE	SEED	POT SIZE	NURS PERIOD (mos.)	GERMIN / GROWTH RATE	PRIORITY/ FIELD NURSERY	COMMENTS
GROUNDCOVERS								
<i>Alyxia oliviformis</i>	maile	G	R	1 gallon tall	15	slow/slow	low	Take creamy pulp off seed, wash, and dry for 2-3 days. Soak overnight and plant; germinate in usually less than 2 weeks, but are slow growers. Field stock better for seed collection. Long, infrequent, germination times (6 mos.) and slow growth make maile an ineffective restoration groundcover although a common understory plant in wet-mesic areas. Recommend direct seeding in the field when large numbers of fruit are available as well as in book pots. Outplant at book pot or 4 inch size. More info available at http://pdcs.ctahr.hawaii.edu:591/hawnprop/
<i>Carex wahuensis</i>	ncn	G		book pots 4 inch	6 6	moderate/fast	high	Sow seeds in book pots after hot water soak, re-sow non-germinations. Can take up to 8 months to germinate, but they usually come up all at once. Hearty and very functional for controlling erosion on slopes with its fibrous root system and its one of the few understory / fullsun ground covers. Produces more seeds planted in the ground vs. in pots.
<i>Plumbago zeylanica</i>	iliee	G		book pots 4 inch	5	moderate/fast	low	Easiest from cuttings, although plants should have fully developed root system before outplanting. Pest resistant. Suitable for cover in dry-mesic shaded to sunny areas. Plant in clusters in large quantities otherwise years before it dominates as aggressive groundcover.
<i>Rumex albescens</i>	huahuako	G		Dibbles Book pots	4	fast/fast	high/YES	Very fast growth re-sow over non-germinators in book pots or directly in short boys. Tolerates pots over long periods. Needs full root system before outplanting. Suitable for cliff areas and landslides. Direct sowing on site recommended.

Appendix 5C: Phytosanitation Standards and Guidelines

The objective of this document is to state the level of sanitation that will be required during ex-situ operations. Sanitation is a key factor in reintroduction/ augmentation by preventing the introduction of foreign organisms into the wild. All plants to be used in reintroduction/ augmentation projects in this plan will be rigorously checked for compliance with the requirements described in the narrative below:

REQUIREMENTS

1. Nursery Certification by Department of Agriculture (Plant Quarantine Branch)

The Department of Agriculture (DOA) developed this certification process for plant growers in Hawai'i that want to export their goods out of state. The nursery certification encompasses various aspects of plant production ranging from general sanitation, to standards of nursery conditions, to pest control. Complying with the certification requirements will require the facilities and equipment to provide clean plants and the absence of nematodes in all plant pots. Examples of the minimal Department of Agriculture certification requirements as of 1999 are as follows. Plants or plant parts used must be:

1. Propagated from clean (nematode- and virus-free) seed or from cuttings taken at least 12 inches above the ground.
2. Planted in suitable material prepared or treated to assure freedom from burrowing nematodes.
3. Grown in sterilized pots, containers or beds.
4. Placed on sterilized benches or sterilized supports which are at least 18 inches above ground or floor level.
5. Protected from contamination until delivery.

2. Nursery/ Growing area

- The nursery ground must be free from weeds, live roots and other plant material. The floor shall be paved, or covered with coarse gravel to insure that no dirt areas are exposed. The walkways must be paved with concrete, black top or gravel.
- A six feet buffer zone around the growing area must be free from any vegetation.
- The plants must be grown in an enclosed area to prevent weed seeds from blowing into pots.
- Plants and aerial roots shall not be grown lower than 18 inches from the ground level to top of benches.
- Water hoses must be kept off the ground.
- No plants are to be placed over the propagative stock (hanging containers or secondary benches), nor under the benches to prevent contamination to plant material.

3. Media

- The grower must use media that is free from weeds, weed seeds, pathogens and pests.
- Media must be stored on a concrete slab in an enclosed area (e.g. in bins that are covered, or warehouse)

4. General Sanitation

- The grower must sterilize tools regularly.
- The grower must keep growing area, benches, and work surfaces free from threats (eg. Weeds, nematodes, pathogens...).
- The workers shall also maintain the same requirements of cleanliness.
- Benches and plant boxes, used pots, flats and implements must be washed free from soil.
- All dead, diseased or infected material in or around the pots should be appropriately disposed of on a daily basis.
- Dead, diseased or decaying plant material should be pruned off with sterilized tools (and re-sterilized between cuts) to prevent further contamination (e.g. flaming tools).
- Adequate spacing between plants is necessary in order to have good air circulation between and around the plants to prevent pest problems.
- Propagules must be free from threats (e.g. pathogens, nematodes etc.). Use appropriate methods to clean seeds (e.g. fungicides or dilute bleach solution).

5. Threat Control program

*PLEASE NOTE: The use of pesticides is governed by state and federal regulations. Ensure pesticide use is in compliance with the law, and follow all label directions. If there are any questions, please contact the State of Hawaii, Department of Agriculture Pesticide Division for further information.

- It should be noted that if restricted pesticides are used, the applicator must be a certified pesticide applicator.
- The grower must have a monitoring and spraying program for each threat category.
- A copy of all the monitoring and spraying schedules, plant species treated, threat/pest treated, last time sprayed, and chemicals used should be kept in a log book.
- See the Threat Monitoring and Control appendix for more information on specific threats.
 - Look for signs and symptoms.
 - Identify the target pests (make sure it is a pest and not a beneficial insect).
 - Monitor for pests presence and their levels of abundance.
 - Know their life cycle.
 - Monitor on a weekly basis.
- Contact your local agriculture extension agent or Department of Agriculture agent for proper identification, up-to-date chemicals and current control practices.

QUARANTINE FACILITY

In order for a facility to be used as a quarantine facility, it must meet the requirements stated in the sanitation guidelines above as well as the following requirements:

- The quarantine facility must have insect screening on all walls and roof of the greenhouse.
- A daily walk-through of the facility is required to inspect the quarantined plants for possible threat problems.
- Inspection of plant material will be done prior to outplanting by a qualified inspector.
- Length of time in quarantine: At least two weeks, three weeks if the plants show susceptibility particularly to disease (Note: at least 10 days is required to detect insects, 3 weeks to detect fungal diseases).

TRANSPORTATION

- Use a vehicle free from threats (e.g. arthropods, mollusks, pathogens etc.) to transport plants. The storage area of the vehicle shall be enclosed to protect the plants from wind damage and potential threat problems.

OUTPLANTING

- For outplanting guidelines, refer to HRPRG guidelines, and follow Alien Species Protocols.
- Clothes, gear, tools, and other planting equipment should be free from foreign substances.
- Use on site mulch if needed instead of bringing in to site.

Phytosanitation Checklist

- Nursery facility walkways covered with coarse gravel or paved with good drainage
- Plastic/Metal Benches at least 18” above ground
- No vegetation within six feet of growing area
- Growing area, walls and roof, must be enclosed
- Insect screening used over vents (if applicable)
- Adequate storage for media (concrete/paved floor and enclosed on all sides)
- Adequate mixing and pouring and storage areas for pesticides
- No plants over or under growing area
- Water hoses kept off ground
- Adequate facility for washing and disinfecting pots
- Regular inspections by greenhouse staff

Equipment

- Use of sterilized tools and benches, disinfected pots and trays (if reused), and DOA-approved media.
- Use of yellow and blue sticky traps to detect infestations early
- Clean transportation vehicle to pick up and drop plants at other sites
- Be prepared to detect and control pests, and have proper equipment and training available to conduct daily inspections (e.g. magnifying glass)
- Adequate chemical application equipment and Personal Protective Equipment

Chemical

- Compliance with State D.O.A. regulation regarding use of all pesticides
- Completion of State Restricted Use Pesticide Applicator Certification
- Prepared to apply broad and narrow spectrum fungicides, herbicides and insecticides for prevention and control
- Prepared to spray greenhouse disinfectant (Contact DOA for a list of approved chemicals)
- Must be prepared to provide a spray schedule and history

Cultural

- Benches cleaned when rotating crops at least every other month
- Appropriate watering schedule to prevent pests (i.e. not too wet)
- Watering/irrigation done to prevent splash-over into adjacent pots
- Dying/dead material removed daily
- Plants spaced on benches to allow for adequate air movement and drying
- Propagules inspected and cleaned before planting
- Workers wearing clean clothing and shoes

Threat Monitoring and Control

This reference is provided for the nursery grower to help identify threats, their signs and symptoms and suggested methods for their control. This is just a general summary of threats, for more information contact your local agriculture extension agent, university professor, or Department of Agriculture personnel.

1. Arthropod Monitoring and Control

- Look for signs and symptoms.
- Identify the target pests (make sure it is a pest and not a beneficial insect).
- Monitor for pests presence and their levels of abundance.
- Know their life cycle.
- Monitor on a weekly basis.
- Contact your local agriculture extension agent or Department of Agriculture agent for proper identification, up-to-date chemicals and current control practices.

a) **Ants:**

- **DESCRIPTION:** There are many types of ants that affect plants in the nursery as well as in the wild. If needed, collect a specimen and have it properly identified by someone from the Department of Agriculture, University of Hawaii Department of entomology, or any other qualified agency.
- **SIGNS AND SYMPTOMS:** Ants are usually found on plants that have scale, mealy bug or any other insect that produces honeydew. The ants farm these insects for the honeydew they produce. They can be seen crawling all over the plant and/or pot. "Tunnels" built by ants that are made out of potting media from the pot can be found on the stems protecting insects that produce honeydew.
- **CONTROL:** There are two distinct types of ants to control. One type is sugar loving and the other prefers an oil-based food. Bait for ants at first sign of presence. If population increases, find and destroy the nest.

b) **Aphids:**

- **DESCRIPTION:** There are many types of aphids that attack plants; however, all of them are soft-bodied and have piercing sucking mouthparts. Their bodies are pear-shaped and can range in colors from yellow to green to black. Aphids secrete a sweet, sticky substance, which is called honeydew. Ants farm aphids for a constant source of honeydew, which is the ant's source of food. The females bear live young. If needed,

collect a specimen and have it properly identified by someone from the Department of Agriculture, University of Hawaii Department of entomology, or any other qualified agency. Once they reproduce, they can have many generations a year.

- **SIGNS AND SYMPTOMS:** When aphids are present on the plant, pale yellow spots are visible on the foliage. Also, leaves may be curled, puckered or stunted. Presence of sticky honeydew is also a good indicator of aphids. Sooty mold may be visible growing on the honeydew. Check under leaves and at growing points for aphid infestation.
- **CONTROL:** Be aware that there are several beneficial insects that prey on aphids. If population numbers increase, spray insecticide as directed on the chemical label. Just a note: aphids are usually attracted to plants over-fertilized with nitrogen.

c) **Beetles:**

- **DESCRIPTION:** Beetles range in size, shape and color; however all have hard bodies and wings (Ball, 1990). They have chewing mouthparts.
- **SIGNS AND SYMPTOMS:** Check for chewed up plant parts such as leaves and flowers. If left unattended, the beetle can totally denude the plant.
- **CONTROL:** Manually pick beetles from the plant by hand. Remove leaf litter around the plant to eliminate suitable habitat.

d) **Black Twig Borer:**

- **DESCRIPTION:** Adult females are twice as big as the males at about 1/16 inch long and are shiny black in color. The males are reddish-brown in color and can't fly. The entire life cycle can take about a month to complete (Tenbrink, 1994). They have chewing mouthparts.
- **SIGNS AND SYMPTOMS:** Stems become weakened and breakage often occurs. Look for small round holes. The twig borers will create holes in the branches and create a living area. Die back of the plant is not caused by the borers feeding on the plant. Instead, it is caused by the physical infestation and the introduction of pathogens (Tenbrink, 1994).
- **CONTROL:** Remove and destroy infested parts. There may be some biological control insects, but more information is needed. Not too much is known about control methods.

e) **(True) Bugs:**

- **DESCRIPTION:** True bugs range in body shape, size and color. Typically, the body is shield shaped and about 1/6-1/2 in long (Ball, 1990). When smashed, they often exude a distinct odor. They have piercing-sucking mouthparts.
- **SIGNS AND SYMPTOMS:** The infested plant may have disfigured growth such as discolored spots, stunted growth, or wilted shoot tips (Ball, 1990).
- **CONTROL:** If infestation is low, hand pick the insects. Clean the area surrounding the plant of leaf litter to decrease suitable habitat.

f) **Cutworms:**

- **DESCRIPTION:** Cutworms are soft-bodied caterpillars that are dull gray or brown in color, and are 1 to 2 inches in length. They are nocturnal feeders that find refuge in the

soil or leaf litter during the day. As adults, they change into moths. The females lay the eggs in the soil, and they can produce an average of 5 generations a year. (Ball, 1990).

- **SIGNS AND SYPTOMS:** If seedlings are mowed down or chomped down near the soil line, that's a good indicator of cutworm damage. Some cutworms also attack the seedlings from below the soil line, damaging the roots and causing the plants to wilt. (Ball, 1990).
- **CONTROL:** Put up biological, chemical or physical barriers around the seedlings to deter the cutworms. There may be some beneficial biological control.

g) Leafhoppers:

- **DESCRIPTION:** Leafhoppers have wedge-shaped bodies that are 1/8-1/4in long. They have a hunched look to them since their folded wings are slightly protruding from their bodies. (Ball, 1990 and Kessing, 1993). They range in colors from green, brown or yellow. They are not very active, however, when disturbed, they can jump suddenly or move sideways with agility. They have piercing-sucking mouthparts and can spread virus (Ball, 1990).
- **SIGNS AND SYMPTOMS:** They feed on all part of the plant (except the roots). As they feed, toxins are released into the plant causing yellowing or discoloration. Leaves will turn yellow and fall off. Leafhoppers excrete honeydew, so ants and sooty mold may be present. (Ball, 1990)
- **CONTROL:** There may be some beneficial biological control (eg. Mymarid wasp) (Kessing, 1993). Keep area around plants clear of leaf litter and weeds.

h) Mealy bugs:

- **DESCRIPTION:** Mealy bugs have piercing-sucking mouthparts, and can attack either the foliage or the root system, depending on the species. They are mobile throughout their lifecycle. Depending of the species, males are relatively short-lived, living an average of 27 days, while the females can live around 115 days (Martin, 1992). Their bodies are covered with a white waxy substance that gives it a "mealy" look (Tenbrink, 1993).
- **SIGNS AND SYMPTOMS:** Leaves will look droopy and the areas they feed on will be yellow and discolored. They excrete honeydew, which can cover portions of the plant. Look for sooty mold, which grows on honeydew. If ants are present, that's a good indicator that mealy bugs are there. They can be vectors of pathogens.
- **CONTROL:** There may be some beneficial biological control (eg. Parasitic wasps). Mixing white oil with the chemical will aid in smothering the scale.

i) Scale:

- **DESCRIPTION:** Scales are related to mealy bugs and aphids, and have bodies that range from 1/12 inch to 1/5 inch (Ball, 1990). Most scales are only mobile during the first stage of their lifecycle. Usually, after their first instar, the female scales become immobile attaching themselves to the plant and form a protective coat. This protective coat can vary from cottony white masses to waxy shells. Males, if present, are not able to feed since they don't have mouthparts. The females either lay eggs or bear live

young under the protective scale (Mau, 1992). Several generations can be produced per year. (Ball, 1990)

- **SIGNS AND SYMPTOMS:** Areas where they are feeding on will turn yellow and may drop. They excrete honeydew can cover portions of the plant. Look for sooty mold, which grows on honeydew. If ants are present, that's a good indicator that scales are there. They can be vectors of pathogens.
- **CONTROL:** There may be some beneficial biological control (e.g. Parasitic wasps). Spraying the scale during their mobile stage is the most effective chemical practice. The dead scales are persistent on the plant, so check the scale population prior to spraying (it may just be dead scale shells). Just a note: Over use of nitrogen fertilizer can encourage growth of scale attracted to succulent new growth.

j) Spider mites:

- **DESCRIPTION:** Spider mites are extremely tiny. Adult females, which are larger than the males, are not any bigger than 1/20 inch (UCDANR, 1995). They have piercing-sucking mouthparts that they use to feed on the underside of leaves and flowers. As they feed, toxins are injected into the plant that result in distorted growth and discoloration of the plant. New generations can be produced as quickly as 2 weeks if the conditions are right (Ball, 1990).
- **SIGNS AND SYMPTOMS:** Check the underside of leaves and on flowers for webbing and tiny excrement pellets as this will indicate the presence of spider mites. Also, if the foliage begins to turn yellow and develop a dry, sandpapery texture, or become distorted in growth that is a good indicator of spider mites. To check whether the spider mites are still on the plant, use a hand lens and examine the underside of leaves. Tap the branch tip or leaves while holding a white paper underneath to catch the spider mites. (Ball, 1990; UCDANR, 1995)
- **CONTROL:** There may be some beneficial biological control (eg. Parasitic mites and ladybird beetles). Spider mites thrive in hot, dry, dusty conditions. The warmer the conditions, the faster they reproduce. Make sure the plants have adequate water because when plants are water-stressed, they are more susceptible to spider mite damage. Be aware that some chemicals such as carbaryl and pyrethroids can actually increase spider mite production (UCDANR, 1995).

k) Thrips:

- **DESCRIPTION:** The adult thrips are winged and are less than 1/25 inch long. They are shiny and usually black or yellow in color. They can have around 8 generations per year. They have a rasping mouthpart. They thrive in dry environments so make sure the plants are adequately misted and watered. (Ball, 1990)
- **SIGNS AND SYMPTOMS:** Check the new growing tips or buds for thrips. If the leaves are curled, or if tiny, black excrement on the leaves is visible, that's good indicator that thrips are present. Also, if there is dried tissue on the leaves, or discoloration or disfiguration of the leaves or flowers, that can be another indication of thrips. (Ball, 1990 and UCDANR, 1996).
- **CONTROL:** There may be some beneficial biological control (eg. Predatory mites). Prune affected flowers and foliage, and dispose of properly. Use sticky traps to

monitor. Keep plants adequately watered, and do not let it become water-stressed. (Ball, 1990 and UCDANR, 1996).

1) Whitefly:

- **DESCRIPTION:** Whiteflies are white, tiny moth-like four-winged insects with piercing-sucking mouthparts. The immature whiteflies resemble aphids, however they are legless and not very mobile once they start feeding. (Ball, 1990 and Flint, 1995). They produce many generations per year, sometimes one generation in less than three weeks depending on the temperature. They thrive in warmer climates. (Flint, 1995)
- **SIGNS AND SYMPTOMS:** Check the underside of the leaves for whiteflies. If present, the leaves will prematurely turn yellow and then fall off. The plant growth will also be stunted. Whiteflies produce honeydew, so check for presence of sooty mold or ants.
- **CONTROL:** There may be some beneficial biological control (eg. Parasitic wasp). Use sticky traps to monitor the whitefly population on a weekly basis in conjunction with a weekly foliage inspection. (Flint, 1995). Horticultural soaps and other insecticides can be effective in controlling the population. “Try to time treatments when your monitoring results indicate that most of the population is in the first, second, or third instar stage.” (Flint, 1995). When spraying, make sure there is good coverage of insecticides to the underside of the leaves.

2. Weed Monitoring and Control

- Any plant in the pot other than the designated plant is considered a weed.
- Monitor on a weekly basis.
- Install weed mat in and around the growing area.
- Have a buffer area around the growing area/nursery of at least 6 feet
- Enclose growing area to prevent weed seeds from blowing in to pots.
- Pull weeds from pots and growing area as they come up. Do not let them go to seed.
- If weed problem gets out of hand, apply herbicide.
- Contact your local agriculture extension agent or Department of Agriculture agent for proper identification, up-to-date chemicals and current control practices.

3. Nematode Monitoring and Control

- Look for signs and symptoms.
 - Identify the target pests (make sure it is a nematode).
 - Know their life cycle.
 - Monitor on a weekly basis.
 - Due to the fact that there are many different nematodes, contact your local agriculture extension agent or Department of Agriculture agent for proper identification, up-to-date chemicals and current control practices.
-
- **DESCRIPTION:** Nematodes are tiny, microscopic, worm-like organisms that are usually translucent with a white hue, and have bodies that are covered by a tough cuticle. (Ball, 1990).
 - **SIGNS AND SYMPTOMS:** In general, plants affected by nematodes look unhealthy or stunted. It is difficult to identify nematode damage, but with root-knot nematodes can you see the actual damage, which are galls on the roots. Look for plants that look sickly

for no apparent reason. Chlorotic leaves or yellow patches on the plant, wilting, and stunting are the main symptoms to look out for. For a positive identification, a dissection of the root is necessary. If there is nematodes present, the roots will be reduced and have galls. (Holtsmann and McSorley, 1993 and Ferreira and Boley, 1991).

- **CONTROL:** There are a few cultural control steps that can be implemented to prevent the spread of nematodes. Have good sanitation practices like removing and destroying infected parts or plants from the growing area and disposing of them properly. Do not dispose of in the compost piles. There are some nematocides that are no longer recommended for control. It would be best to contact DOA, or a UH Agriculture specialist to check on the species of nematodes, and chemicals to use for controlling nematodes.
- **MONITORING:** To check for root knot nematode: take soil from suspected area and plant susceptible crop like cucumbers, after first true leaves appear, pull seedlings up and carefully wash soil off soil to see if nematode galls are on roots. Another test uses radishes. After 6 days check radish seedlings for galls.

4. Mollusk Monitoring and Control

- Look for signs and symptoms.
- Identify the target pests (make sure it is a pest and not a beneficial insect).
- Monitor for pests presence and their levels of abundance.
- Know their life cycle
- Monitor on a daily basis, usually early morning is best.
- Contact your local agriculture extension agent or Department of Agriculture agent for proper identification, up-to-date chemicals and current control practices.

a) Slug

- **DESCRIPTION:** Slugs are terrestrial mollusks that do not have shells. They have slimy bodies are usually 1 to 2 inches (some can even reach 8 inches) long and travels on a foot that leaves a trail of slime behind. The colors range from white, yellow to black. They have a rasping mouthpiece. The eggs are in translucent-white, individual sacs, which form a cluster, and is usually found in a dark, cool, moist areas or underground. Slugs can produce about 6 generations per year and they take about a year to mature. (Deputy and Murakami, 2000).
- **SIGNS AND SYMPTOMS:** Look for the slime trail, which is usually silver in color. Damage to the plant, such as large ragged holes in leaves, flowers, and stems, is done by the slug. They can quickly defoliate the plant if not controlled. Check the undersides of pots and in drainage hole of the pot to see if they are present. Slugs begin feeding at the bottom of plants and work their way up. (Ball, 1990)
- **CONTROL:** Keep area around plant and in pot clear of leaf litter. Manually dispose of any slugs in growing area. Set up traps to lure slugs and then dispose of them. Set up a physical or chemical barrier to deter slugs. Use baits to kill slugs. (Deputy and Murakami, 2000)

b) Snails

- **DESCRIPTION:** Snails are soft-bodied mollusks that are protected in a shell. They can range in color from cream, pink to gray. The markings on the shell vary from species to

species. They can be found in moist, dark areas, usually coming out at night to feed with their rasping mouthpiece. (Ball, 1990) They produce about 80 eggs at a time, and can lay eggs up to 6 times a year. The eggs are rounded and white in color, and can be found in the upper layer of the soil. The snails mature in two years. (Deputy and Murakami, 2000)

- **SIGNS AND SYMPTOMS:** Look for the slime trail, which is usually silver in color. Damage to the plant, such as large ragged holes in leaves, flowers, and stems, is done by the slug. They can quickly defoliate the plant if not controlled. Check the undersides of pots to see if they are present. (Ball, 1990)
- **CONTROL:** Keep area around plant and in pot clear of leaf litter. Manually dispose of any snails in growing area. Set up traps to lure snails and then dispose of them. Set up a physical or chemical barrier to deter snails. Use baits to kill snails. (Deputy and Murakami, 2000)

5. Pathogen Monitoring and Control

- Look for signs and symptoms.
- Identify the pathogen.
- Know their life cycle.
- Monitor on a daily basis.
- Contact your local agriculture extension agent or Department of Agriculture agent for proper identification, up-to-date chemicals and current control practices.

1. Bacterial disease

- **SIGNS AND SYMPTOMS:** Infected plants often have rotted leaves, stems branches, or tubers, which have a foul odor. When cutting into an infected area, a small amount of whitish or yellowish ooze will seep out. Other symptoms include wilted leaves or stems, or odd shaped galls on the stem or on the roots near the soil line. Symptoms can spread quite quickly by splashing water (such as irrigation or rain) or by infected soil. They can enter a plant either through wounds or through the stomata. (Ball, 1990)
- **CONTROL:** Besides chemical control methods, also remove all infected plants, and wash hands and sterilize tools after handling infected plants. Use good spacing between plants to encourage good air circulation. Clean up and remove diseased plant parts and dispose of them by placing in plastic bag or sealed container right away.

2. Fungal diseases

- **SIGNS AND SYMPTOMS:** Look for rust-colored or powdery-white looking spots on either side of leaves. These spots will eventually make the leaf chlorotic and will eventually kill the leaf tissue. Also, look out for water soaked spots, greasy looking areas, or black streaks or blotches on the leaves or stems. (Ball, 1990).
- **CONTROL:** Besides using fungicide control methods, remove affected areas and dispose of in a plastic bag or a sealed container. Be sure to wash hands and sterilize tools after handling infected plants. Use good spacing between plants to encourage good air circulation. (Ball, 1990)

3. Viral Diseases

- **DESCRIPTION:** “Viruses are basically parasites, multiplying inside their hosts or if no host is available, lying inactive but viable in dead plant material for up to 50 years while waiting for a new victim.” (Ball, 1990. pg345)
- **SIGNS AND SYMPTOMS:** Be aware of plants that have poor overall growth (like stunted leaves, and flowers). There may be yellowish mottling patterns on the leaves, stems or blossoms that make the plant look sickly. (Ball, 1990)
- **CONTROL:** Viruses are spread by insects with piercing-sucking mouthparts such as aphids and leafhoppers. Garden tools and humans are other vectors of viruses. Do not take cuttings from infected plants as the cuttings will also have the virus. Remove and destroy (not in the compost pile) the infected plants, and wash hands and sterilize tools after use. (Ball, 1990)

6. Small Mammals and other pest monitoring and control

- Look for signs and symptoms.
- Identify the target pests.
- Monitor for pests presence and their levels of abundance.
- Know their life cycle
- Monitor on a daily basis.
- Contact your local agriculture extension agent or Department of Agriculture agent for up-to-date chemicals and current control practices.

a) Rats/Mice

- **SIGNS AND SYMPTOMS:** Look for seedlings and/or seeds dug up, uprooted and eaten. Droppings and tracks.
- **CONTROL:** traditional mousetrap and bait. Use good sanitation practices by cleaning up all possible food sources, using rodent-proof containers of metal or glass, and removing tall grass, weeds and shrubby growth.

b) Birds

- **SIGNS AND SYMPTOMS:** Young seedlings and/or buds may be nipped off. Look for droppings and feathers.
- **CONTROL:** Barriers and deterrents like metallic ribbon and owl figures.

c) Toads and Frogs

- **SIGNS AND SYMPTOMS:** Look for evidence of nestling in pots such as vegetation in pots that are smashed or pushed to the side of the pot. Toads and frogs are potential carrier of nematodes.
- **CONTROL:** Do not have standing water anywhere that would make it favorable to toads or frogs. Capture manually and dispose/release in favorable habitat far away from the growing area.

Appendix 5D

Pesticide Chart

Mention of a trademark, company, or proprietary name does not constitute an endorsement, guarantee, or warranty by the author.

**Always check or test for plant sensitivity when using a new pesticide or at higher rates than listed.*

FUNGICIDES/ALGAECIDES:

Product	Primary Active Ingredient(s):	Mode of Action	Class	Toxicity Category	Application rate	Interval	REI (restricted entry interval)	Notes:
Banrot	Thiophanate-methyl (25%) and Etridiazole(15%)	Systemic	Benzimidazoles and Thiazoles	III, IV	12g/3 gal 2 1/4tsp/3 gal	1/week for flats, wilting seedlings due to damping off as needed	12 hrs	Can combine w/ Zerotol, alternate w/ subdue (not good to mix with other pesticides/fertilizers unless adequately trailed)
Sulfur	Elemental sulfur	Contact?	Inorganics	IV	2 to 4 tablespoons/ gal	30 days	24 hrs	Good for mildew of mints, supposedly works on mites(need test trial) spray with water
Subdue	Mefenoxam: (R)-2-[(2,6-dimethylphenyl)-methoxyacetyl-amino]-Proponic acid methyl ester	Systemic	AC	III	7 drops/gallon	1/week for flats	Till spray is dry	Can combine with zerotol, alternate w/ Banrot Possibly phytotoxic -Dave P.
Zerotol (Algae/fungus)	Hydrogen dioxide	Oxidation (kills fungi, bacteria, algae and their spores on contact)			2 oz/ gallon (1:100) 6 oz/gallon for floors	1/week for flats 1/month for floors and benches	0 hrs (none)	3 applications on consecutive days for heavy infestation, can be combined w/ subdue maxx

INSECTICIDES:

Product	Target Pest:	Primary Active Ingredient(s):	Mode of Action	Class	Toxicity Category (toward humans)	Application rate	Interval	REI	Notes:
Amdro	Ants	Hydramethylnon		Miscellaneous	III	Lightly sprinkle around nursery when ants present (see label)	As needed		Use on baseboards and around ant nests, more frequently needed during dry periods
Avid	Mites (red spider, brown, broadleaf)	Abamectin		Insect growth regulator	II	1.2 ml/gallon	As needed	12 hrs	2 applications 14 days for heavy infestation May cause phytotoxicity to mints during hot/dry periods... (use lower concentration)
Cinnamite	Mites (red spider, brown, broadleaf)	Cinnamaldehyde	Contact	Miscellaneous	II	25 mL/gal or (0.85 oz/gal)		4 hrs	Lobelioids, mints highly sensitive Don't apply to stressed plants, causes flower dieback
Concern	Various	Potassium salts of fatty acids				3.5 oz/gal	Spot treatment	0 hrs (none)	Lobelioids, mints sensitive
Dipel DF	Fungus gnats, caterpillars	Bacillus thuringiensis, subsp. kurstaki, strain HD-1		Microbial	II-III	½ - 1 tsp/gal	14 days (also depending on environ. factors, see label)	4 hrs	Larvae must eat dipel deposits to be affected For heavy infestations: 2

									applications 14 days apart
Enstar II	Various, good for green- house white flies	S-Kinoprene		Insect growth regulator		2 ml/gallon (see label)	1 time/per month (see label for curative treatment cycle)	12 hrs	Affects life cycle (no immediate kill) Combine with Maverik for best control
Gnatrol	Fungus gnats	Bacillus thuringiensis, subsp. israelensis, strain 65-52				1 oz/gallon	1 time every week (or as needed after heavy rains)		Stops feeding of larva stage only
Marathon	Green-house whiteflies, mealy bugs, aphids et. al	Imidacloprid	Systemic	Misc.	II	¼ teaspoon/gallon pots 1/8 teaspoon for half gal. pots or 4" pots	Every 2 Months	12 hrs	Takes 2 weeks for full effect, water light to activate, ineffective in water logged soils, no deep watering for 3 waterings, keep soil dry-moist
Merit 2.5 G	Green-house whiteflies, mealy bugs, aphids et.al.	Imidacloprid	Systemic	Miscellaneous	II	2 cups/full yard cart (6 cu. ft)	Mix into media for rare plants when transplanting	12 hrs	Use only for rare plant known to be pest magnets
Merit 75 WP (wetable powder)	Green-house whiteflies, mealy bugs, aphids et.al.		Systemic		II	¼ tsp per 2.5 gal		12 hrs	3 weeks prior to outplanting, no deep watering for 3 waterings, keep soil dry-moist
Mavrik aquaflo	Really good for mites only, combine w/ Enstar II for whitefly infestations	Tau-fluvalinate	Contact			1.2 ml/gallon	1 time/month (see label for curative treatment cycle)	12 hrs	Non phytotoxic, combine w/ Enstar II for max. effectiveness
Orthenex	White-flies, mites,	Acephate	Systemic	Organo-phosphate	II				Mints seem to be sensitive

	aphids, various others.								(showed phyto- toxicity) Good to alternate with seven for whiteflies.
Sevin	Various: Greenhouse whiteflies, mealy bugs, aphids et. al.	Carbaryl	Contact and stomach poison	Carbamate	II-III	1-3 oz/gallon	1 time every 7- 10 days for heavy infestations of	12 hrs	Lobeliods Platydesma, mints, sensitive to repeat spraying, Residue cooks in sun, wash off within a day or two during dry periods
Sulfur	Mites and other insects	Elementary sulfur				Max: 6 tsp/gallon Effective at 2 tsp/gallon	As needed		2 applications 10 days apart, good for controlling fungi too
Talstar F	Mites and other insects	Bifenthrin		Synthetic pyrethrins or pyrethroids	II		1 time/month rotate with other pesticides (Enstar/Mavrik)	12 hrs	2 applications 14 days apart for heavy infestation
Ultrafine	Aphids, mites, thrips	Paraffinic oil	Contact	Oil		2.5 tbs/gallon	As needed (consecutive sprays shouldn't exceed more than once every two weeks)	4 hrs	Mints, lobelioids highly sensitive to paraffinic oil

SNAILS/SLUGS:

Product	Target Pest:	Primary Active Ingredient(s):	Mode of Action	Class	Toxicity Category (toward humans)	Application rate	Interval	REI	Notes:
Deadline	Slugs, snails	Metaldehyde				See label, lightly hand disperse in garden and around outside of nursery or inside PVC pipe on benches	As needed		When pellets get wet, they get moldy (attacked by fungi).
Snail/slug bait (liquid)	Slugs, snails					A few drops around seed flats	As needed		

TOXICITY CATEGORY	SIGNAL WORDS REQUIRED ON LABEL BY EPA	ORAL LD ₅₀ (MG./KG.)	DERMAL LD ₅₀ (M.G./K.G.) 24-HR. EXPOSURE	ORAL DOSAGE TO KILL AN ADULT*
I. Highly Toxic	DANGER, POISON, Plus Skull & Crossbones symbol	0 to 50	0 to 200	A few drops to 1 tsp.
II. Moderately Toxic	WARNING	50 to 500	200 to 2,000	1 tsp. to 2 Tbsp.
III. Slightly Toxic	CAUTION	500 to 5,000	2,000 to 20,000	1 oz. to 1 pt. (1 lb.)
IV. Low Toxicity	CAUTION	>5,000	>20,000	1 pt. (1 lb.) or more