A MANUAL FOR CONTROLLING VOLCANO'S WORST WEEDS

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TABLE OF CONTENTS

Three strategies for controlling weeds—2
Three rules for effective control—4
Manual/mechanical control strategy—6
Chemical control with herbicides—13
Cultural control strategies—31
Rx's for controlling Volcano's worst weeds—44
Himalayan ginger—45
Strawberry guava—47
Tibouchina—49
Himalayan raspberry—52
Faya tree—54
Knotweed—56
Spreading selaginella—56
Blackberry—57
Monbretia—57
English ivy—57
Grasses—58
Bamboo—61
Sedges—62
Other sources of information about weed control--63

THERE ARE THREE MAIN STRATEGIES FOR CONTROLLING WEEDS

The three principle strategies for controlling weeds are: 1) manually or mechanically, 2) chemically with herbicides, and 3) culturally by modifying the ecosystem or environment of the weed. These strategies are applicable to a garden, landscaping, agricultural settings, or native ecosystems. This manual addresses all three strategies because they often need to be applied in an integrated fashion for long-term, low-maintenance weed control and to minimize use of chemicals. The manual emphasizes weed management in native ecosystems in Volcano but many of the same weeds are problems in landscaping, gardens, and agricultural areas, and many of the control strategies and methods work in all of these settings. The manual also includes tactics or specific techniques or "tricks" useful in implementing these strategies. A weed is conventionally defined as an undesirable invasive plant. Obviously, this definition of a weed is from a human perspective. In any case, in the context of native ecosystems, a weed is an invasive non-native plant species.

What is a weed? *The often quoted definition is "a plant out of place." This definition works in our context: A weed is a non-native plant introduced to Hawai`i by humans, intentionally or accidentally, and invading native ecosystems. Native plants are those that got to Hawai`i naturally, without human involvement, by " wind, wave, or wing" and then evolved here.*

Manual/Mechanical

Chemical (herbicides)

Cultural (ecosystem modification), e.g. plantings, mulching.

BEFORE YOU SELECT A WEED CONTROL TECHNIQUE:

1) IDENTIFY THE TARGET WEED
2) UNDERSTAND ITS ECOLOGY

Two weeds invading a forest cleared of kahili ginger

Uprooted spreading selaginella

The first step in pest management, including weed control, is to identify the pest. Proper identification is essential in researching a control method others have used. Identification connects you with all of the accumulated knowledge about the plant in question. One of the best aids in identifying weeds in Hawai`i is the HEAR.org website. This website includes multiple pictures of many of the weed species in the islands. It also includes a FLICR website tp://www.flickr.com/groups/hawaiiplantid/) where you can post your unknown plants and get identifications from other folks using the site (might be quality control issues). You can also look for photos on the google image search website (**http://images.google.com/**). More technical references include *A Tropical Garden Flora* by George Staples and Derral Herbst and the *Manual of the Flowering Plants* of Hawai`i by Warren Wagner and others. These include line drawings, descriptions, and identification keys. Of course, one of the best sources may be in the oral tradition; ask a knowledgeable neighbor.

The second step before beginning control is to learn about the ecology of the species to determine its weak points. The HEAR and CTAHR websites listed on the last page of this manual are helpful. Much of this understanding may come from personal observation. For example, I have learned from personal observation that poha is not a serious weed in native ecosystems. It may form small patches but does not spread aggressively and dies off after a few years. I do not bother controlling poha and enjoy the fruits while the plants persist. On the other hand, spreading selaginella appears to be an increasingly aggressive weed in openings in the forest. It forms dense patches that seem to preclude establishment of native plants. I have attempted to control spreading selaginella by hand-pulling, followed by mulching with tree fern fronds and this did not work I have not tried sheet mulching. However, it readily recovers from tiny, rooted fragments of the shoots. The most effective long-term way of removing spreading selaginella then is chemically with herbicides. Crossbow at 1-2% in water seems to be fairly effective.

THE ARE THREE RULES OF EFFECTIVE WEED CONTROL

Rule #1. PREVENT INVASIONS AND RESPOND RAPIDLY WHEN THEY OCCUR. Regardless of your control strategy--manual/mechanical, chemical, or cultural– the feasibility of control and the amount of time and effort devoted to weed controlled can be made more manageable by two common sense tactics: 1) preventing the dispersal of weeds to your managed site and 2) responding rapidly to new introductions in a timely fashion. Palm grass appeared at my managed site (home forest restoration project) for the first time a few months after heavy equipment was used to put in a driveway and clear tibouchina and in all the areas where the equipment worked. Dispersal could have been prevented by inspecting and clearing the equipment before operating. A logical corollary to prevention is to respond rapidly to any new invasion and eradicate it before a local seed source and seed bank develop and while the invading population is still manageable. For example, a few patches of knotweed appeared in disturbed areas at my managed site but were ignored. Within a couple of years, there were large patches on the edge of the forest. These are now too big to manage by uprooting and will require chemical control.

Small patch of invading knotweed on edge of managed site. Patches this size were ignored and developed into less manageable larger patches that spread into areas to be protected from weeds.

Large patch of knotweed on edge of forest. Patches like these developed after two to three years of ignoring the few small invading plants.

Rule #2. FOLLOW-UP AND BE PERSISTENT. At least some weeds will resprout after a control effort and you can usually count on seedlings appearing. In fact, removal of the parent weed plants will remove competitive plants and sometimes weed control precipitates a flushing of the seed bank. Without timely follow-up, it might take a few short months for the weed to fully recover. A productive regimen for weed control is when you conduct a knock-down in year one, schedule automatic follow-ups in year two and year three. Only after that you can adopt follow-up on an as-needed basis.

THE THREE RULES OF EFFECTIVE WEED CONTROL

Rule #3. PLAN FOR REINVASION OF YOUR CLEARED AREA BY ANOTHER WEED SPECIES.

Often the worst weeds in Volcano may occur in single-species stands, displacing all but taller vegetation. For example, in the Volcano Golf Course subdivision, faya tree forms a closed canopy, sometimes below taller `ōhi`a and koa, displacing virtually all understory plants. In windward Volcano, tibouchina invades abandoned clearings or the edges of the forest, eventually eliminating all other plants except taller trees and some tree ferns. Kahili ginger and strawberry guava will invade the understory of rain forest to form wall-to-wall stands with tree ferns or just an occasional tall shrub. If you remove dense stands of faya tree, tibouchina, kahili ginger, or strawberry guava, then you create open habitat available for colonization by other weed species, which are adapted to spread into new, unoccupied sites. This is certainly true of removing faya tree and tibouchina stands which will rather quickly become invaded by fast growing, light loving plants such as grasses, blackberry, and other invasive plants. Typically removing both kahili ginger or strawberry guava in rain forest with native tree and tree fern canopy will facilitate the recovery of native species which are present on site to rain down seeds or spores. If you remove just kahili ginger or just strawberry guava, then you can expect the other species to gradually but eventually grow into the sites cleared of its main competitor. Anticipate subsequent weed invasions and the need to manage new weed species.

Tibouchina and invasive grass. Tibouchina once grew to the road's edge and more. After control, this open site was invaded by alien, light-loving grasses. One option is to resign yourself to mowing and weed eating the grass; another option is to plant māmaki and other fast-growing, shade-producing plants to suppress the grasses.

Strawberry guava growing vigorously in site cleared of kahili ginger. The former dominance of ginger can be inferred from the big, recently killed rhizomes. Strawberry guava must be controlled too, particularly since it has been released from competition with ginger.

THE MANUAL/MECHANICAL CONTROL STRATEGY

Manual/mechanical control is carried out by uprooting weeds by hand (manually) or by using a tool to uproot, cut, or control weeds in some fashion (mechanically). The tool could be a machete, axe, pick, saw, weed eater, rototiller, mower, or bulldozer. Local examples of manual control in native ecosystems include pulling up knotweed or kahili ginger by hand. Local examples of mechanical control include bulldozing tibouchina or even in some cases kahili ginger where trees are spaced widely.

Some of the tools useful in mechanical weed control

One of the main advantages of manual/mechanical control is that it avoids the use of chemicals. The main disadvantages is that it is often labor-intensive so that it is not feasible for large areas. In addition, most mechanical control techniques emphasize removing a portion of the aerial biomass and may not affect live tissue above ground or in the root system. As a result, resprouting often occurs requiring repetitive treatments. For example, using a chain saw, you can cut down weed trees. However, most trees resprout when cut, from the remaining stem, the root collar (the junction of the stem and roots at ground level), or from root sprouts. These resprouts will require additional cutting, often multiple times.

NON-HERBICIDAL TACTICS TO MAKE MANUAL/MECHANICAL CONTROL MORE EFFECTIVE

Tactic 1: Prevent Resprouting by Blocking Light

Step 1. Flush cut stump

Step 2. Cover flush-cut stumps with foil or black plastic; be sure to cover the root collar

One technique to make mechanical control more effective, without the use of herbicides, is to follow-up initial control by preventing resprouting. This can sometimes be effected by simple techniques to cut off light for the remaining above-ground plant parts. Blocking light can be carried out effectively with faya trees and a number of other woody plants by cutting the stumps close to the ground to reduce the surface area supporting potential re-sprouts. Sprouts may arise from the sides of the remaining above ground stem or the root collar at ground level. Then the remaining stems can be covered with tin foil or heavy black plastic. The foil or black plastic needs to be firmly anchored. Sometimes sprouts, even with little or no light, may grow and penetrate or dislodge the covering. If resprouting is suppressed by the covering on the cut-off stump, then the plant will use up remaining reserves in the root system, without new growth to produce food and maintain the reserves of the plant. This technique does not work well with species such as tibouchina, strawberry guava, and Himalayan raspberry which will resprout from the roots, not just the cut-off stump.

NON-HERBICIDAL TACTICS TO MAKE MAUAL/MECHANICAL CONTROL MORE EFFECTIVE

Tactic 2. Remove Resprouts to Exhaust Reserves—Faya Tree Example

Faya tree resprouting from stump after mechanical control.

Flush-cut faya tree stump on tree fused to an `ōhi`a. Faya resprouted from the cut. The tree was killed by removing re-sprouts a few times over a couple of years.

A second follow-up technique to improve the efficacy of mechanical control involves removal of resprouting material. To assist, woody plants should first be cut off as close as practicable to the ground. When they resprout, manually remove or clip them off. This is effective with faya tree over a one or two year period when a few generations of sprouts are snapped off by hand. The tin foil and the snap-off methods work on the same physiological strategy: they prevent the plant from rebuilding its reserves through photosynthesis. Once the reserves are exhausted in the roots, then the plant dies. For this reason, do not let the sprouts become too large and re-build reserves in the roots. If you have to use clippers to cut them, you have probably let them become too large and have become, in effect, machines to restore the plants reserves. This technique probably does not work well with woody species that re-sprout from the roots such as tibouchina, strawberry guava, and Himalayan raspberry.

COMPOST DUG-UP KAHILI GINGER AND PILE CUT-OFF TIBOUCHINA

New pile of ginger rhizomes ready to be chopped up and composted

Composting kahili ginger rhizomes with fresh additions of kitchen scraps and plastic cover pulled back.

A challenge of manual and mechanical control is the disposal and control of dug-up or cut-off ends which may resprout. This is a special problem in the wet climate of east Hawai`i. For example, dug-up kahili ginger rhizomes, even fairly small fragments, will resprout. (Dug up roots usually do not and rhizomes mechanically shredded generally do not re-sprout if the shredded pieces are relatively small—run through the shredder twice). The rhizomes can be disposed of at Volcano Transfer Station's green waste bin or more sustainably by composting on-site. Composting kahili ginger requires mature patience because it may take two or three years. Simply cover the piles of dug-up rhizomes with two sheets of 6 mil black plastic to block light and prevent them from resprouting. The rhizomes will retain sufficient moisture in the compost for decomposition. Resprouting may occur under the black plasic but the sprouts are etiolated (long, leggy, without much or any chlorophyll) and will die on their own if the two layers of black plastic are weighed down on the edge. Without turning the compost or adding fertilizer or other greens, it takes 2-3 years for usable compost to form. Composting of kahili ginger rhizomes can be accelerated by first cutting up the rhizomes to increase surface area and the rate of decomposition. Running the rhizomes through a shredder is ideal but even using a cane knife or machete helps speed up the process. Adding kitchen scraps and fertilizer and turning the compost occasionally will also accelerate the process noticeably.

A TECHNIQUE TO PREVENT RESPROUTING OF UPROOTED STEMS

A “pullable” waiawī stem about two ft tall

Uprooting a small strawberry guava stem

Pulled-up stem placed in tree fern to keep of ground

Smaller stems of some weedy trees and shrubs can be controlled by manually uprooting them. Strawberry guava or waiawī provides an example. However, resprouting and rerooting often occur if the pulled up stems are placed on the ground, particularly during rainy periods. If you are pulling a manageable number of stems, then they can be hung in a tree or tree fern (trees probably provide a drier surface). When dealing with larger numbers of uprooted stems, then try making a pile as described in the next slide. Incidentally, hanging kahili ginger rarely works; this species is an efficient epiphyte and usually resprouts if hung.

A TECHNIQUE FOR KILLING AND DISPOSING OF LARGE VOLUMES OF CUT-OFF ENDS

In some cases, hanging uprooted or cut-off ends in trees is not a feasible tactic. You may have too many plants or they are too large. In these cases, the cut-off stems can be piled and left to decompose with minimal or no resprouting if measures are taken to prevent regrowth. Tibouchina, strawberry guava, or other woody plants can be cut, piled, and covered with a thick, light-shielding tarp or black, 6 mil plastic. Ideally the covering should be large enough to have a skirting on the ground to cover stems on the periphery. The covering minimizes or precludes resprouting, allowing the pile to begin decomposing. Another piling technique does not require covering the plant. Instead, the cut-off stems are kept off the ground with logs or dead stems to minimize resprouting and rerooting. Another disposal technique does not require piling. If you are using chemical control, then also treat the cut-off end just after you apply herbicide to the cut stump. In this way, the herbicide will be translocated in the cut-off end, killing it. These stems can be piled or left on the ground to die.

Pile of tibouchina stems. The cut-ends Of these stems were treated with herbicide At the same time the cut stumps were. In spite of this, one stem re-sprouted.

Piled stems of tibouchina. The cut ends were not treated with herbicide. They were laid on a platform of old logs to keep the bottom stems off the ground and prevent them from re-sprouting and re-rooting.

Covered tibouchina re-sprouting on edge of black plastic where there was no skirting to cover stems on the lower edge of the pile

MANUAL/MECHANICAL DOES NOT ALWAYS WORK

Manual and mechanical control may be impractical or technically unfeasible, especially in non-agricultural situations where machinery cannot typically be used and you may need to control weeds at a large scale. Follow-up methods such as covering stems, removing sprouts, mulching, or planting of other vegetation to suppress weeds may not be effective on your target species work or cannot be employed on the scale needed. For example, it is relatively easy to uproot small blackberry stems by hand. However, it is difficult to remove the roots which pulling stimulates to resprout. Pulling up young blackberry plants, in fact, may make matters worse; it multiplies the number of stems. A chemical approach may make more sense in this situation. Spraying the foliage with 0.5% Garlon 3A is highly effective at killing blackberry and kills the roots to preclude re-sprouting. Localized application of heavy mulch, such as sheet mulching, has not been tried but may also be effective after pulling.

Six inch tall blackberry

Blackberry root

Blackberry roots left in soil usually re-sprout

CHEMICAL CONTROL WITH HERBICIDES

Herbicides often play an important role in weed control because of their efficacy and efficiency, especially in controlling weeds over large areas, at which scale manual, mechanical, or cultural techniques are not practical. For example, it may be feasible to control kahili ginger in a one-half acre tract of forest using a machete and exhausting the reserves of the rhizomes by faithfully removing sprouts every week. However, this may not be feasible for a six acre patch of forest. .Also, some plants are very difficult or impossible to control with manual, mechanical, or cultural techniques; almost always an herbicide can be found that works on them. For example, it is very difficult to impossible to kill Kikuyu grass by pulling, even followed by thick mats of mulch. Kikuyu grass has above ground runners that can exit the mulch, even when there is little light and they are not photosynthetic. It also has underground rhizomes that spread beyond mulch layers.

Three, non-restricted "over the counter" herbicides: Crossbow, Roundup, and Escort.

Modern herbicides go through extensive testing for short-term toxicity to users, non-target organisms, and the environment. If used correctly, following label instructions, these toxic effects can be avoided. For example, Garlon 3A causes irreversible eye damage as a concentrate. This potential toxic effect is noted on the label which prescribes appropriate personal protective equipment (chemical goggles) to protect the eyes while mixing. However, what cannot be tested are chronic exposure over long periods of time and in the environmentherbicides on page five of *Herbicidal Control Methods for Pastures and Natural Areas of Hawai`i* by Philip Motooka, Lincoln Ching, and Guy Nagai (http://www2.ctahr.hawaii.edu/oc/freepubs/pdf/wc-8.pdf). The authors argue for the safety of modern herbicides and address common concerns. Balanced information about specific herbicides is most accessible on the web. For example, a very readable and apparently objective fact sheet for glyphosate, the active ingredient in Roundup, can be found at http://environmentalcommons.org/cetos/criticalhabitat/glyphosate.pdf. You probably need to make up your own mind. A balanced article on herbicide toxicity can be found at http://ipm.illinois.edu/pubs/iapmh/11chapter.pdf

A frequently asked question by herbicide novices is "Do we need a special license to use herbicides?" A few herbicides are "restricted use" and sold only to Certified Pest Applicators. The herbicide label will indicate if it is restricted. Certification can be obtained through a short, valuable training course set up by the Hawai`i Department of Agriculture, Pesticide Branch, in Hilo. Most herbicides are not restricted use and are sold over the counter. For example, the three herbicides pictured here, Crossbow, Roundup, and Escort, which control almost all upper Puna weeds, are not restricted use herbicides. Training, self-taught, and careful following of the herbicide label is all that is needed.

HOW TO STAY SAFE AND LEGAL USING HERBICIDES: FOLLOW THE LABEL

The most important rule to follow with herbicide use is to understand the saying repeated in many pesticide use classes: "The Label is the Law." The meaning of this phrase is that the legal uses of an herbicide are specified on the label ("It is a violation of Federal law to use this product in a manner inconsistent with its labeling"). You can be fined for using an herbicide inconsistent with the prescribed uses or carrying out a prohibited use specified by the label. For example, there is a local label for ginger control in Hawaii using Escort herbicide. It restricts herbicide application to the rhizomes and prohibits broadcast spraying with high pressure equipment. One of my neighbors did a foliar spray of kahili ginger foliage with a high pressure sprayer over two acres. He was not fined because this was done in a residential area (Hawai`i Department of Agriculture scrutinizes use more closely on farms and large conservation areas with lots of pesticide use) and I did not turn him into the HDOA. There was no fine, but young trees, native shrubs, small native herbs and ferns that were in the same layer of the forest at the kahili ginger were decimated by the spraying. The label rules not only keep you legal; they help keep people, non-target species, and the environment safe. Read the label thoroughly before using.

Herbicide labels contain important information for use:

- ►Active ingredients by common name and chemical formula name, e.g. the trade name is Garlon 3A; the active ingredient is triclopyr
- ►Personal protective equipment (PPE), e.g., use of goggles
- ►Hazards to humans and animals, e.g., corneal damage from concentrate
- ►User safety recommendations, e.g. how to wash gloves after use
- ►First aid for exposure, e.g. wash eyes for 20 minutes if exposed
- ►Areas to avoid, e.g. crops, irrigation canals
- ►Proper storage and disposal
- ►Recommended & maximum dosage and rates per area
- ►Approved methods of application, e.g., can use frill or girdle on trees
- ►Approved sites, forests and non-crop areas

Labels provided by distributor and available on-line (google, e.g., "Garlon 3A label")

BE AWARE OF SPECIAL LOCAL NEEDS LABELS FOR YOUR AREA

Special local needs labels will give specific guidance using herbicides on plants in your area. To find them, google, e.g., "Special Local Needs Escort Hawaii." An example of a Special Local Needs label for Escort on ginger species is provided below: This special local needs label complements the general Escort label applicable to all areas and can also be found on manufacturers website with the general label.

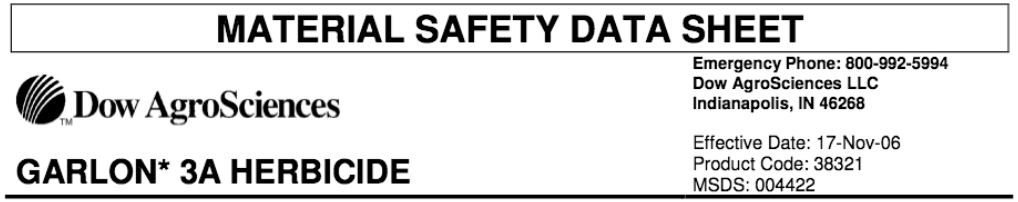
SPECIAL LOCAL NEED
24(C)LABELING
DuPont Crop Protection
DUPONTTM ESCORT XP HERBICIDE
SPOT TREATMENT FOR CONTROL OF
WILD GINGER IN THE STATE OF HAWAII
FOR DISTRIBUTION AND USE ONLY WITHIN THE STATE OF HAWAII
DUPONT TM ESCORT® XP HERBICIDE
EPA Reg. No 352-439
SPOT TREATMENT FOR THE CONTROL OF WILD GINGER
EPA SLN No. HI-060004
Active Ingredient: Metsulfuron methylMethyl 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-
2-yl)amino]carbonyl]amino]sulfonyl]benzoate …….....….. 60% (by weight)
Inert Ingredients ……..…. 40% (by
weight)_____TOTAL 100%
GENERAL INFORMATION:
Methods of Application: Spot applications may be made using backpack sprayers, hand-held tanks, spray bottles, or lab squirt DuPont™ ESCORT® XP herbicide is a dispersible granule that applicator bottles. Apply to the leaves, exposed rhizomes, and is mixed in water and applied as a spray. The use of ESCORT®cut surface or stalks and rhizomes. Avoid run-off or over spray.XP under this Special Local Need registration is specific to spot Care should be taken to avoid overspray onto soil by directing application(s) for control of wild ginger (Hedychium sp.) in spray at ginger surface rhizomes or foliage only. forests (montane wet forest, mesic forest), forest margins, and other mid to high elevation wildland areas where this plant is ESCORT® XP may be combined with a non-ionic surfactant to invasive. improve foliar uptake. DIRECTIONS FOR USE: It is a violation of Federal law to use this product in a manner The use of a dye is recommended to track sprayed solution.inconsistent with its labeling. Frequency of Applications: Spot applications to limit regrowth may be made on an as-needed basis.. Target pest: Wild ginger (Hedychium sp.). PRECAUTIONS Application Sites: Forests, forest margins, and access roads and trails. Do not apply using high volume power sprayers. Do not apply as a broadcast application .Application Rate: Apply 0.067 - 0.133 ounces (1.9 - 3.8 Do not apply this product through any type of irrigation system.grams) of ESCORT® XP per gallon of water (1/2 - 1 gram ESCORT® XP per liter of water) for spot treatments, Avoid spray drift near streams or irrigation ditches .exceed 3 ounces (85 grams) per acre per year within the spot For product information, call 1-888-6-DUPONT. You may also treatment area. contact 1-800-441-3637 for emergency medical treatment information. For product information call 1-888-6-DUPONT
H - 65282

READ THE MSDS BEFORE USING AN HERBICIDE

There is a second document prepared for each registered herbicide, the Material Safety Data Sheet or MSDS. Parts of the MSDS are technical and not useful for the field applicator, e.g. information about reporting for Superfund Amendments and Reauthorization Act of 1986. However, the MSDS provides valuable information for safe use and background on health and environmental effects. The MSDS also helps to answer questions about safety of the pesticide in a summary fashion, but unfortunately in some cases only in technical terms not accessible to the average pesticide user.

MSDS contain the following information:

- ►First aid with notes to physicians or medics
- ►Measures for accidental spills
- ►Details on PPE for prolonged or frequent exposure
- ►Potential health effects from exposure such as cancer or birth defects
- ►Fate of the chemical in the environmental and toxicity to different organisms



MATERIAL SAFETY DATA SHEET

Dow AgroSciences

GARLON* 3A HERBICIDE

Emergency Phone: 800-992-5994
Dow AgroSciences LLC
Indianapolis, IN 46268

Effective Date: 17-Nov-06
Product Code: 38321
MSDS: 004422

MSDS are available from distributor (ask) or online, e.g., google "Garlon 3A MSDS"

HOW TO STAY SAFE APPLYING HERBICIDES

Most herbicide labels list these user safety recommendations to reduce exposure:

►Wash hands before eating, drinking, chewing gum, using tobacco, or using the toilet.
►Remove clothing immediately if herbicide gets inside. Then wash or shower immediately and put on clean clothing.
►Remove PPE (personal protective equipment) immediately after using. Wash/Shower immediately.
►Wash outside of gloves before removing; then wash inside and let drain and dry before using again.
►Wash clothing worn while applying herbicide separately from other laundry.
►Discard clothing which becomes thoroughly drenched.
►Avoid inhaling during application by positioning relative to direction of spray and wind; avoid fine spray

Here is some common sense advice about PPE:

►Herbicide labels and MSDS list minimum required PPE for that herbicide. Always wear these items or better.
►The minimum required on the least toxic herbicides are long-sleeved shirt, long pants, shoes and socks, washable hat, and chemical-resistant gloves.
►Add high-top rubber boots to your list of minimum required clothing
►Consider also wearing goggles, respirator, and tyvek suit for maximum protection of eyes, lungs, and skin for all herbicides, even if the label does not require these PPE.

Tyvek suits are ideal for herbicide application. They resist chemicals, breathe, and can be washed and used multiple times or discarded. Available in paint departments of some hardware stores, e.g., HPM. Cost about $9 each.

Chemical-resistant gloves. The label will so indicate: >14 mil, butyl rubber, natural rubber, neoprene rubber, or nitrile rubber (latex gloves are handy but not rated as chemical resistant).

Respirator. Be sure to get high quality and filter specifically for chemicarl, not dust or gases. Make sure it fits snugly. Note that most herbicides recommended in this manual do not require a respirator.

Rubber boots are much safer than leather boots. They can be washed after use and do not absorb and accumulate herbicide. Insoles help to make them more comfortable.

HOW TO BE SAFE WHEN MIXING HERBICIDES

SAFETY:

►Follow all the safety instructions on the label for use when mixing. Be aware that you are working with concentrate that may be more dangerous to the applicator or to the environment than the dilute solutions that you apply to weeds.

►At a minimum, use the required PPE and always wear safety glasses and chemical-resistant gloves.

►Do the mixing in a shallow plastic tub so that any spills will be contained.

► Here is a user-friendly web site on safety precautions and PPE for mixing herbicides, based on protocols used by the Nature Conservancy, Forest Service, and other organizations: http://www.ehow.com/how_6743282_mix-herbicides.html

Handy, spill-proof mixing tray for herbicides.

SOME HELPFUL HINTS FOR SELECTING/MIXING HERBICIDES

►**Plant species vary in their sensitivity to different herbicides.** If you are spraying ginger rhizomes with Escort herbicide and encounter a Himalayan raspberry or strawberry guava, it might be tempting to douse them too. However, this could be pointless. They are sensitive to Garlon 3A but may very well not be sensitive to Escort. Another example: many grasses are sensitive to Roundup but not to Garlon. Another example is that Garlon 4 may be more effective killing tibouchina than Garlon 3A. Some herbicides tend to affect a broad range of species, e.g., Roundup, and are considered to be "non-selective". Selective herbicides kill a limited range of plants, e.g., Fusilade mostly kills monocots such as grasses and sedges but not broadleaf plants The take home lessons are that you need to find the right herbicide for the weed you are trying to control, and you might be able to avoid damage to non-target species by using a selective herbicide.

►**Often "less is more."** Often applicators will increase the dosage when a plant proves to be sensitive to a particular herbicide, thinking that "more is better" or the appearance of a faster kill indicates control of the plant. However, higher doses may rapidly kill aerial portions of the plants ("burn the leaves") , disabling physiological function of the plant and reducing translocation of the herbicide through living phloem cells to the roots. As a result, roots may live so that high doses may result in re-sprouting. A slow death, with lower doses, permitting translocation to the roots may be more effective in the long term.

(right) **Herbicide-killed patch of Kikuyu grass.** A very dilute solution of Roundup, 0.75%, was used, based on research at Hawai`i Volcanoes National Park. Higher concentrations did not work as well in terms of long term kill. There were no signs of herbicide damage to this patch of Kikuyu grass for over a month after application, so the grass was killed slowly with herbicide getting to the rhizomes to kill them too.

MORE HELPFUL HINTS ON MIXING HERBICIDES

►**The most effective dose/application method comes from research or experience, not label recommendation.** Label recommendation are a broad guideline, applicable to many species, with an emphasis on North American mainland species. To find an effective herbicide, concentration, or method of application for Hawaiian weeds, check local sources, e.g., HEAR website (http://hear.org/pier/commonnames/languages/English/index.html). Another website with control information is http://www.ctahr.hawaii.edu/invweed/weedsHi.html. If you cannot find a local recommendation for your target species, or these sources only indicate which herbicides your target weed is sensitive to, you may need to do some trial and error testing. Stay below the maximum allowable label dosage and try different dosages and application techniques, with at least five plants for each dosage or application method. Monitoring should be conducted for at least a year because of the potential for delayed resprouting.

►**Mix up what you need for that day; if extra, cover mixture to store.** Some herbicides, such as Garlon 3A, will photo-oxidize when diluted. Ideally, just enough herbicide should be mixed for use that day. Placing the herbicide solution (e.g., trigger spray bottle or backpack sprayer) in a dark environment helps prevent photo-oxidation, e.g., place inside a black plastic bag.

Mixed solution of Garlon 3A. This herbicide photo-oxidizes when in a dilute solution. Photo-oxidation can be inhibited by storing it in a black plastic bag.

►**How to deal with surplus herbicide solution.** Say you left your mixed solution of Garlon 3A exposed to light for a week between applications. Pouring this down the drain or on the ground is a violation of the label and pointless pollution. However, the label allows you to dispose of surplus solution or rinsate by applying it to target plants, even though it may be in dosages too low to be effective. One trick is to add enough concentrate to the solution to make a fresh batch, and then apply this regularly to the target weeds.

HELPFUL HINTS ON ECONOMICS OF HERBICIDE PURCHASE

Herbicides are a better buy when purchased in larger containers. Some herbicides such as Garlon 3A or Garlon 4 are sold only in 2-1/2 gallon pails. However, you may need only a portion of that volume. A good strategy is to sell the surplus to your neighbors who are probably in the same situation of needing less volume than the cheaper large containers provide. You can use old herbicide container, which are superior in that they are opaque, by triple rinsing with soap and water and labeling the new container with the name of the new herbicide.

A one gallon container of Crossbow. It also can be purchased in one quart containers for nearly twice the amount per unit volume. Say you need two quarts. One strategy is to buy the gallon and sell unneeded quantities to your neighbors.

Container of equivalent carriers (solvents) for Crossbow, including diesel and Ultra-Pure Oil. Both diesel and the oil are approved for use with Crossbow for cut stump treatments. The diesel seems to be just as effective and costs about 20X less than the oil.

HELPFUL HINTS ON TIMING OF HERBICIDE APPLICATION

►**Timeliness of application can be important.** **W**eed species are more susceptible to herbicide treatments under certain conditions than others, and the right conditions may vary from species to species. Weeds are generally more susceptible under the following conditions:

1) when actively growing with new, fully expanded, "soft" leaves;
2) when actively growing after energy reserves are low, e.g. after a previous herbicide treatment or after drought (it might be best to wait until they start actively growing again); or
3) when the weather is dry (and maybe warm and sunny) because (rain washes away herbicide before it can be absorbed, but with soil moisture is adequate for activity and growth of the plant.

Note: Some species may be easier to kill after mechanically cutting them back and treating the resprouting foliage. The initial cutting weakens the plant, making it use up reserves in the roots. Treating resprouting foliage may not be effective or may take a lot of fine tuning to find the right solution mixture. Also, the reduction in absorbing surface and thus the amount of active ingredient applied to the target plant is reduced.

(above) **Kahili ginger flushing with new growth.** Note that the top leaves are lighter in color and the uppermost leaf is just unrolling, all indicating active growth and susceptibility to herbicide. Herbicide tests conducted at Volcanoes National Park and Waikamoi Nature Conservancy Preserve showed that less herbicide was needed in the summer months when the plants were actively growing, as above. Kahili ginger plants from June-September can be killed with a solution of Escort at 1 gram/liter of water, the maximum allowed by the Special Local Needs Label for controlling ginger in Hawai`i. More Escort, higher than the label amount, is required in the winter months when plants are not actively growing.

HOW TO MIX A HERBICIDE SOLUTION

The prescription in this manual for Escort herbicide is given in grams per liter of water. There is a handy cross-calibrated measuring cylinder provided with the herbicide that measures grams as a volume that you simply mix with water. All the other prescriptions in this manual are in percentages, e.g., a solution of 0.5% Garlon 3A in water is used as a foliar spray on blackberry or a 15% solutions of Crossbow in diesel is used on a cut stump treatment of tibouchina. In all cases, the herbicide percentage refers to the percentage of herbicide in a total solution, which might be water, diesel, or a dye used to mark sprayed plants. For example, one liter (1000 milliliters or ml) of a 15% solution of Crossbow has 150 ml of Crossbow and 850 ml of diesel.

Here is how to mix up a percentage solution:

Example: 10% solution of Garlon 3A in a 25 fluid ounce (fl oz) trigger spray bottle.

Step 1. Add water to about the half way mark in the trigger spray bottle.
Step 2. Measure out 2.5 fl oz for Garlon 3A concentrate in a separate container (baby bottles work great!)l
Step 3. Pour the Garlon into the trigger spray bottle.
Step 4. Fill up the trigger spray bottle to the 25 fluid ounce mark.

Example: 2% solution of Roundup in a l0 liter (l)backpack sprayer.

Step 1. Make sure your sprayer is calibrated. You may need to add your own marks on the side by calibrating the sprayer gallon by gallon or liter by liter, depending on the units you prefer to work with (hint, metric is easier).
Step 2. Fill the sprayer with water about half way.
Step 3. Calculate the quantity in a 2% solutions. Here is the math: 0.02 X 10 liters or 10,000 milliliters (ml) = 200 ml.
Step 4. Add the 200 ml of Roundup to the sprayer.
Step 5. Add water up to the 10 liter mark.

Herbicide labels provide mixing instructions in volume of concentrate per volume of water or other carrier, rarely in percentages. Sometimes ranges are given for concentrations. These are general guidelines and not specific prescriptions for the species that are listed on the label for that application and dosage. They can be ignored for Volcano weeds described in this manual. The percentage concentrations of herbicide solutions prescribed in the manual have been vetted by research or practice in the national park and are less than the maximum dosage allowed by label.

Some handy conversion factors: 1000 ml = 1 liter; 128 fl oz = 1 gallon; 32 fl oz = 1 quart

A HERBICIDE MIXING SKILL YOU MIGHT NEED SOME TIME

Calculating dilutions for % active ingredient, rather than product. Recommendations for control from the CTAHR and HEAR website (see last page of manual), are often expressed as percentage active ingredient rather than percentage trade name, e.g., glyphosate (Roundup), triclopyr amine (Garlon 3A), Imazypyr (Arsenal**).** This first takes some label reading. For example, in Garlon 3A, triclopyr amine is 44.4%. If a 10% solution of triclopyr is recommended for control of weed X, then you have to calculate how much Garlon 3A to add to how much water to make a 10% solution of active ingredient. If a 4% solution of Garlon 3A is 5.1 fluid ounces in 128 fluid ounces (1 gallon) of water, then 4% of the active ingredient, would, intuitively, be a little more than twice this amount. You can set this up as a ratio and proportion problem: 5.12/44.4 = X/100 or 44.4X=512 = 11.5 fl oz

Some useful, readily available measuring devices for mixing herbicides. Some of these are calibrated in fluid ounces and others in milliliters, and still others in both systems.

Backpack sprayer. Note the self-inscribed 10 liter calibration mark to the left of the sprayer wand.

MOST COMMONLY USED METHODS OF HERBICIDE APPLICATION

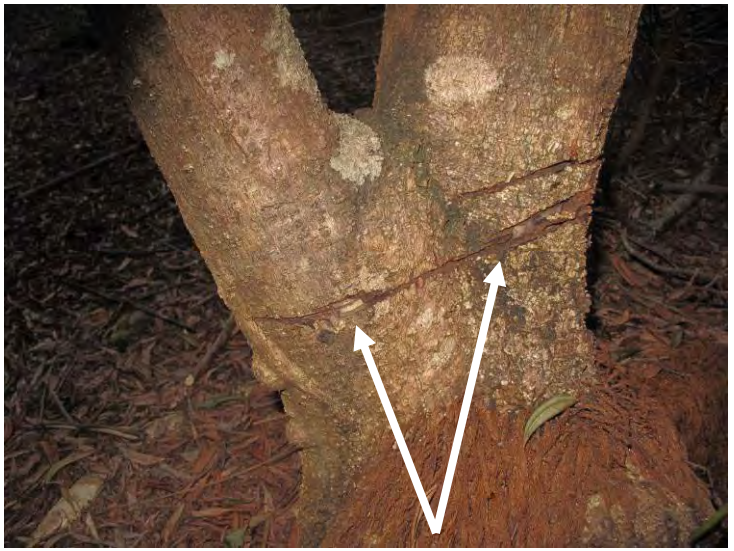
Cut-stump. This method is commonly used with weedy trees, shrubs, and vines. The stump is cut as close to the ground as practicable to aid in translocation of herbicide to the roots. Make sure no green shoots are left below the cut. The small sprouts below your cut stump should be cut or snapped off at the same time the stump is cut. It is probably helpful to squirt some herbicide on the cut surfaces of these sprouts or side branches. Be aware that herbicides do not move laterally as well as vertically in the plant so these shoots may persist to keep the plant alive to recover later.

It is best to apply herbicide **immediately** to all cut surfaces. It is tempting to keep cutting other plants and then come back to spray the cut stump. If you are a solo applicator, stop cutting and apply the herbicide just after exposing a cut surface because it is absorbed and translocated more effectively when the cut is fresh. It may be efficient to work in pairs on some species with one person cutting and the other immediately behind, spraying. If you are treating a large cut-stump, herbicide needs to be applied only to the ring of live tissue on the periphery of the stem, just inside the bark. Herbicide is translocated in phloem cells here. Make sure the entire ring is doused with herbicide up to the point of run-off because the herbicide does not translocate well laterally in the phloem. With smaller stems, such as the ones illustrated below, you will inevitably spray the entire cut surface. In wet environments, if you also spray the cut surface of the cut-off end, you can prevent resprouting and rerooting if this stem is left on the ground.

Cut-stump treatment of strawberry guava.

FRILL-GIRDLE AND CHAIN SAW GIRDLE CUT SURFACE TREATMENTS

Frill-girdle type of cut-surface technique



Chain saw girdle

Frill-girdle. This is a cut surface treatment around an intact, upright stem or trunk. Instead of cutting off the stem to access the phloem cells, the bark is cut through with downward hacks penetrating the live tissue of the plant, including the phloem that translocates herbicides. A cane knife or machete is a handy tool for frill girdle because the natural downward cuts can create a cup to temporarily hold herbicide solution. A chain saw can be used in a technique called chain saw girdling. The chain saw girdle is created by holding the blade horizontally and cutting shallowly through the bark into the living tissue ringing the outside of the bark. Frill-girdle and chain saw girdle, like cut stump, are most effective when carried out as close to the ground as practicable to increase prospects for effective translocation to the roots. It is also critical to completely encircle the stem, cutting into the entire ring of vascular tissue because herbicides do not move well laterally. Apply herbicide to the cut surface immediately after the cutting is completed. It may take many months to see signs of injury from frill-girdle and many more months for the plant to die. One of the advantages in a native forest setting is avoiding felling green trees, causing damage to nearby vegetation. Instead frill-girdled trees will slow decompose in an upright location and fall to the ground, piece-by-piece. In addition, light will enter the forest more gradually. Cutting down trees often precipitates a rapid invasion of grasses and other weeds.

BASAL BARK METHOD OF APPLICATION

Basal Bark. Basal bark applications involve spraying the lower 12-18 inches of the stem of woody plants. Herbicide is mixed with either petroleum or vegetable based oil or diesel, per label instructions. Garlon 4 (or Redeem), Crossbow, and Milestone are three herbicides labeled for this use in Hawai`i. The spray is applied to the bark all the way around the tree. It is not effective if any basal surface is missed. It works most effectively on smaller woody plants with diameters less than six inches and smooth bark. The herbicide is applied in a penetrating oil carrier. Basal bark has been used effectively on Miconia and somewhat effectively with smaller faya tree (but not nearly as effective at cut-stump and frill-girdle application). It is used less commonly than cut surface treatments and foliar applications. Thin-line is a variant of basal bark treatment in which the herbicide is applied in a narrow ring around the stem.

WHAT DO YOU DO IF THE CUT-STUMP RESPOUTS?

Resprouting tibouchina. Cut below the level of the sprouts and apply 15% Crossbow in diesel.

Some cut stumps will resprout, even when you meticulously follow the control prescription. The most effective way to re-treat a resprouting cut-stump is to cut it again below the original cut and as close to the ground as practicable. Immediately apply the herbicide prescribed for cut-stumps at the same concentration to the fresh cut-stump. It might be tempting to treat the foliage since this avoids re-cutting the stump. You can do this effectively if the correct dosage has been determined by researchers or other practitoners. You know that the plant is sensitive to that active ingredient since it is known to kill cut-stumps. However, the most effective dosage for foliage will undoubtedly be much lower than that for cut-stump. The latter dosage will simply burn the leaves, cause poor translocation to the roots, and not kill the target plant.

TIPS ON EFFECTIVE AND SAFE FOLIAR APPLICATION

Backpack sprayers are useful for larger scale foliar spraying such as the rhizomes of extensive stands of kahili ginger.

Foliar applications are typically used on herbaceous broad-leaf plants, grasses, and sedges. It is intended for green, soft parts of the plant, not woody parts or bark. Foliar is sometimes used on low-growing shrubs and vines that do not require spraying above one's head. One of the big advantages of cut surface treatments is that they have highly localized application with little drift or effects on non-target plants. Foliar applications have higher risk for collateral damage. One of the common errors in foliar application is to apply high volumes of herbicide solution. This results in greater amounts of active ingredient applied, burning of leaves, with resulting poor translocation to the under ground parts of the plant and poor kill. It can also mean spray drift and injury to nearby plants. The rule of thumb for foliar spraying is to apply solution up to, but not beyond the point of run-off. Think of misting the foliage rather than soaking the foliage. Another common error is to apply the herbicide incompletely, missing parts of the plant. Again, herbicides translocate vertically much better than horizontally so missed foliage may not be killed if not sprayed. Foliar spraying is probably more weather dependent than cut surface application. Spray on dry days so that herbicide is not washed off by rain but has time to be absorbed. Some practitioners report that foliar applications appear to be more effective when conducted on warm, sunny days.

Trigger spray bottles are very useful for spot foliar treatments such as small ginger seedlings and particularly for cut surfacetreatment. With a sharpie, label the bottle the name of the herbicide, its concentration, and the carrier, e.g., 15% Crossbow in diesel.

HOW TO AVOID INJURY TO NON-TARGET PLANTS WHEN SPRAYING

One of the main drawbacks of using herbicides, especially applied as a foliar spray, is the potential for well-intended herbicide applications to target weed, to injure or kill desirable non-target plants. This does not happen frequently with cut-stump or frill treatments because herbicide is applied specifically to these cut surfaces, and this is the reason cut-surface methods are favored for weed control in native ecosystems. Non-target injury is most common in foliar treatments and with herbicides that have residual effects in the soil (i.e., persist in the soil and are taken up by roots or germinating seeds). You will have less collateral damage if you twist the nozzle of your spray rig for larger droplets, less mist, hence less spray-drift. Avoid spraying under windy conditions. Another tactic that helps is to avoid locking the trigger mechanism or always holding down the trigger. Pull the trigger when you are right over your target weed. A simple but labor intensive technique, probably most appropriate to small scale projects, is illustrated below. One trick, useful in small scale operations or very sensitive areas, is illustrated below.

A patch of alien carpet grass invading the forest floor. To control the carpet grass, typically a 1% solution of Roundup will be used. Roundup is a non-selective herbicide and drift or poor handling of the spray may result in Injury to the young tree fern.

The tree fern is saved by the bucket. A five-gallon dry wall mud bucket was placed over the tree fern to protect it from errant spray. It was removed immediately after spraying to be used on another plant to be protected.

CULTURAL CONTROL STRATEGIES

Weeds can also be managed by techniques that modify the ecosystems in which weeds are growing. These techniques create unfavorable conditions for the establishment, growth, and reproduction of weed species. Ecosystem modification may include creating changes in composition of plant communities and plant species, or light, soil, nutrient regimes of the site. This approach is often called the cultural strategy for weed management, probably because it frequently involves culturing (growing), planting, or encouraging plants that might compete with weeds. One of the advantages is that it avoids or minimizes the use of herbicides to control weeds. Another advantage is that some techniques, such as plantings that inhibit weeds, may potentially be more long term in their effects and preclude repeated treatments, and thus are less labor-intensive in the long run.

One of the disadvantages of the ecosystem modification strategy is that modifying ecosystems to affect weeds might require greater knowledge and skill. than manual/mechanical or chemical control. On the other hand, this may be considered an advantage because of the challenge and learning involved. In a number of cases, there may be no effective and acceptable cultural technique to control weeds. For example, kahili ginger invades native rain forest in Volcano. With the goal of restoration native forest infested with this weed, particularly restoring the native understory plants, there is no acceptable way to modify the ecosystem to remove and keep out ginger. Kahili ginger is extremely shade-tolerant so plantings of tree ferns and other native plants would not create conditions unfavorable for ginger.

An example of a highly effective cultural technique to control weeds. This front yard ecosystem has been modified by compacting soil and adding gravel to discourage weeds. It works for that purpose, but not if forest protection and restoration is a goal of the homeowner. By the way, the current homeowners bought the property cleared as above; don't blame them.

USE PLANTINGS TO SUPPRESS/INHIBIT WEEDS

One of the most widely used cultural techniques used in native ecosystem restoration is to plant fast-growing native plants to suppress weed species. These plantings inhibit weed establishment by reducing light and casting leaf litter on the ground. The litter effect is probably due to depth and shading, but may involve the release of (allelopathic) chemicals that inhibit seed germination. Plantings probably work best when they are fast growing species that form a dense layer of vegetation fairly close to the ground. It typically works best in fairly open conditions rather than in dense a forest where you can better grow these inhibiting shrubs.

Nursery-grown māmaki, in pots, poised to be planted.

Seven year old māmaki with no weeds beneath it. The planting grew rapidly with the larger individuals creating a crown 10 feet in diameter and eight feet tall, with some branches growing near the ground. Grasses, successful invaders in adjacent areas, could not survive under the low, thick māmaki canopy. The accumulated leaf litter may also help prevent weed establishment.

USE TREE FERNS TO SUPPRESS WEEDS

Hāpu`u inhibiting weed establishment. Tree ferns form a nearly closed canopy in this rain forest site and naturally suppress most weeds, except for a few such as kahili ginger and strawberry guava.

Thick tree fern plantings. Surplus tree ferns removed from a cleared house site were purchased from neighbors and planted at fairly close spacing. They now form a closed, weed-inhibiting canopy. The naturally occurring native shrubs beneath the tree ferns contribute to low light levels and weed inhibition.

Observing patterns of natural weed suppression in native ecosystems provides insights into species selection with native plants for cultural weed suppression. In the Hawaiian rain forest, hāpu`u tree ferns, naturally occurring tree ferns are one of the main impediments to the establishment of weedy alien species. Experimental clearing of tree ferns fronds to create light gaps in the canopy in the `Ōla`a Forest of Hawai`i Volcanoes National Park, where tree ferns form a continuous canopy, resulted in the rapid invasion of weed species. Tree ferns not only greatly reduce light penetrating to the forest floor, their dying and falling fronds create a thick bed of long lasting litter on the ground. The fronds break down very slowly and serve as a sink for nutrients. In contrast to most weeds which evolved without tree ferns, native plants have evolved to live with densely spaced hāpu`u. Native plants can continue to regenerate on platforms above the leaf litter by growing on elevated nurse logs or as epiphytes on the sides of tree ferns or trees. Observing such patterns in natural rain forest ecosystems suggest species and spacing to use as weed suppressing plantings.

USE PLANTINGS TO CONTROL WEEDS

(right) **2003, a "before" picture.** This area was farmed from 1916 to 1964. When abandoned, the site was invaded by tibouchina.

(right) **2010, six years after planting.** The tree ferns have recovered from transplanting and the fronds are again large and vigorous forming a closed canopy 5-10 feet above the ground. Planted māmaki have grown into dense shrubs. Weed problems are now minimal where plantings are vigorous and dense. Planting shade-creating shrubs or ferns on the edge of the stand is highly effective in thwarting light-loving weeds which typically grow well on the margins of a forest stand where light levels are high.

ULUHE IS A MISUNDERSTOOD WORLD CLASS WEED INHIBITOR

Uluhe in understory of `ōhi`a forest

Many people do not like uluhe because of its impenetrability and the misconception that it is a forest killer. They misunderstand the ecological role of uluhe in forest succession and do not appreciate its value in keeping out weeds. Uluhe is native to Hawai`i and is the weed mat of young or recovering rain forests. Uluhe's dense, overlapping fronds and copious leaf litter suppress weeds. Uluhe is an early successional species, and is naturally abundant in younger rain forest. In some disturbed older forest, it may also become abundant when the disturbance force, such as cattle grazing, is removed or the forest recovers from a natural wave of dieback of `ōhi`a. Uluhe slows down the establishment of many native plant species but it does not invade established forest and smother established native vegetation. As forests age, it is gradually replaced by tree ferns, mid canopy trees, and other native species which eventually grow up through small gaps or thin spots in the uluhe mat. However, you can expect that removing large patches of uluhe may result in a grass invasion. Uluhe grows best at higher levels of light, an ideal habitat for grass. The most ecologically effective strategy to reduce the cover of uluhe is incrementally, in small patches, to minimize sudden light penetration to the forest floor and to allow native plants to establish in the small gaps created by uluhe removal, rather than grass. It is best to clear uluhe by hand and leave the dead fronds on the forest floor as mulch to inhibit grass invasion. Clearing with machinery not only removes the litter/mulch, but this disturbs the soil and favors weed invasion too. Usually there are no weed problems following removal of naturally very small patches of uluhe. These tend to be on their way out anyway in shady forest environments. Often tree ferns invade these areas so you are simply accelerating plant succession.

RESTORE NATIVE ECOSYSTEMS TO DISCOURAGE WEEDS

Carefully chosen plantings can effectively inhibit or prevent weeds from establishing. In native ecosystems, so can native plants recovering on their own following the removal of disturbances sources, e.g., feral pigs, or by removing dense stands of non-native weeds. This allows for the natural recovery of native plant species and the replacement of understory in Hawaiian rain forest. Native trees and understory shrubs and ferns contribute to the exclusion of some alien plants. Tree ferns particularly contribute significantly to weed control. Still, some rain forest weeds in Volcano are very shade-tolerant species such as kahili ginger and strawberry guava that can become established in dense, shady native forest, particularly given some history of disturbance.

Young cohort of native tree seedlings and young tree ferns, growing from seeds or spores. Kahili ginger was removed from this site six years before.

EXCLUDING FERAL PIGS HELPS NATIVE PLANTS AND HINDERS WEEDS

Disturbance is one of the main factors for the spread and establishment of weeds in Hawai`i. Forested pit craters, with steep sides and no access to feral animals such as pigs, sheep, or goats have very few or almost no weeds. Weedy species are typically adapted to becoming established in physically disturbed soil. Without ungulates there is little loss of tree ferns, no soil disturbance, and reduced dispersal of weed seeds. Weed control in rain forest areas of Volcano is significantly helped by excluding pigs.

A pig-proof fence under construction. Although costly, hog-wire fence is the most effective way of excluding feral pigs.

Pig-killed hāpu`u. Feral pigs damage and kill downed tree ferns by tearing through the root mantle and eating the starch-filled center of the fern. Rats then gain entry to the fern and continue to gnaw away at the starch. In the case above, damage from pigs and rats cut through the trunk and detached the fronds Pigs are capable of knocking over small hāpu`u ferns and `ama`u ferns. Tree ferns are one of the main inhibitors to the establishment of weeds in Hawaiian rain forest.

SHEET MULCHING IS AN EFFECTIVE CULTURAL TECHNIQUE FOR CONTROLLING WEEDS IN SMALL AREAS

Weeds kept at bay under sheet mulch and plantings of natives. The area under the plantings of māmaki, hāpu`u, and `ōhi`a was sheet mulched to prevent it turning into a grass stand like that on the adjacent right edge of the image.

A SHEET MULCHING PROFILE

…….. Dead tree fern fronds

******** Ginger or other green leaves**

XXXXX Cardboard

++++++ Paper

====== Knocked-back weeds

Soil Soil Soil Soil Soil

Note: If you are working in a garden setting, then you might want to insert compost or manure as the first layer above knocked-back weeds.

If you are controlling weeds intensively at a small scale, sheet mulching may be an effective technique. It also mulches and enriches the soil. Finally, it saves trips to the recycling bin at the transfer station with car loads of paper and cardboard or to green waste in Hilo. Sheet mulching is a favorite tool of permaculture practitioners and it relies on abundant resources found in Volcano, such as kahili ginger shoots and tree fern fronds. Sheet mulching as described above will break down, except for remains of dead tree fern fronds, in about six months in windward Volcano.

SHEET MULCHING 101 FOR VOLCANO

Step 1: Knock back weeds

The first step in sheet mulching is to knock back the weeds. Pull or cut weeds close to ground. You can do this by hand or with a sickle or weed eater. If they can readily be uprooted, then do so. However, uprooting is not essential; the point is to weaken them and make them rely on their reserves. Sheet mulching probably is most effective with grasses, sedges, and broad leaf herbaceous plants. Some plants, particularly grasses such as Wainaku or Kikuyu grass, with long underground runners and deep reserves, are a challenge to control by sheet mulching. You may also have some woody plants such as tibouchina or guava which re-sprout and may outlast the sheet mulching or penetrate it. Consider treating these species first with an herbicide. Give them a few months before you cover them. During this time, the herbicides will translocate to the roots and cause damage here if the aerial portions are left alone and not buried by sheet mulching.

Cutting grass with a sickle

Uproot plants by hand when practicable but uprooting Is not essential

Consider using an herbicide with plants that send up shoots from underground rhizomes

ADDING A DOUBLE "BROWN" LAYER TO THE SHEET MULCH COMPOST

Sheet mulching is basic composting. You are alternating carbon rich or "brown layers" such as paper and cardboard and dead tree fern fronds with nitrogen rich "green" layers represented by kahili ginger shoots.

Step 2. Lay down paper on top of weeds

Black and white newspapers may be the most environmentally friendly method because the print ink is soy-based. For American made paper products, color ink is now supposed to be soy-based. For some high end glossy magazines, lead and other heavy metals may be used in the dyes.

Adding on at least 6-8 sheets of paper over knocked-back weeds

Step 3. Then add a layer of cardboard

Then add a layer or two of cardboard. One of the challenges with cardboard is the non-biodegradable strapping tape and plastic labels used now on cardboard packaging. It can be removed before placing the cardboard or picked after decomposition of the cardboard.

Placing cardboard on top of the paper

ADD A READILY AVAILBLE GREEN LAYER

Step 4. Place a layer of green plant material on the cardboard.

Removing fruiting heads from ginger. This reduces the number of ginger seedlings you will need to pull out after the sheet mulching decomposes.

Ginger leaves make a highly efficient green layer in the mulch. Also useful are the large leaves of ape, kalo, or banana. The main function of this layer is to complement the newspaper in blocking light to suppress weeds. It also adds nitrogen-rich green material for composting purposes and has a short-term aesthetic function of helping hide the cardboard and newspaper. Be sure to remove fruiting material before using as mulch to avoid a new generation of seedlings after the sheet mulching breaks down. One of the problems with using kahili ginger leaves is that a few fruits or seeds, even if you cut off the inflorescenceces, may be hidden in the leaves so ginger seedlings will occasionally emerge some months later after the sheet mulching disappears.

DEAD TREE FERN FRONDS ARE THE PERFECT TOP LAYER

Step 5. Use dead tree fern fronds as the top sheet

Dead tree fern fronds make an effective top dressing to the sheet mulching strata. They add carbon to the mix, with the nitrogen-rich ginger leaves just below them. They are nutrient sinks (accumulators) in the rain forest ecosystem and even dry, dead leaves may be fairly rich in inorganic nutrients. In addition, they break down slowly so that all that remains after the newspaper, cardboard, and ginger leaves decomposes is a thin layer of tree fern leaf litter. One word of caution in using tree fern fronds. Make a practice of using dead and brown fronds for use in sheet mulching. If you cut off dying and still partly yellow or green fronds you can gradually over time harm to the donor plant. These partly live fronds are undoutedly re-translocating nutrients back to the rest of the tree fern. If you remove them year after year you will be taking nutrients away from the donor plant.

Dead tree fern fronds are the top, long-lasting layer in sheet mulching

SHEET MULCHING DOES ITS JOB AND THEN DISAPPEARS

September, 2010. Note grass to left of māmaki prior to sheet mulching (from p 37)

Same scene, May, 2011. Grass is gone; sheet mulching has decomposed.

R_X'S FOR CONTROLLING VOLCANO'S WORST WEEDS

Note: see also CTAHR and HEAR references on last page of manual for other techniques

HOW TO CONTROL KAHILI GINGER, MANUALLY/MECHANICALLY

One foot tall ginger with two shoots. This plants looks easy to pull up.

However, there is a lot of rhizome mass hidden beneath the leaf litter on the forest floor. The pick pictured here is an effective model (available only at Garden Exchange)

Here is the extricated rhizome mass. The long dangling roots do not resprout so no problem if roots remain in the soil after rhizome removal.

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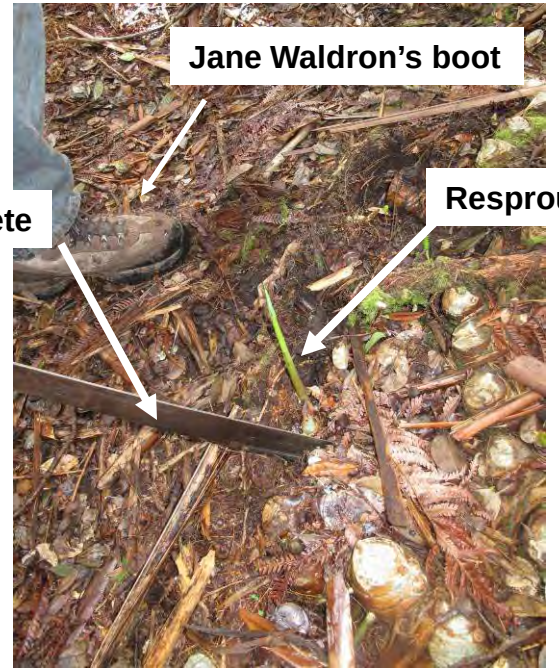
Controlling kahili ginger manually and mechanically is virtuous exercise and avoids the use of chemicals. However, it is time consuming and labor-intensive to implement over large areas and it takes lots of follow-up and self-discipline. Uprooting ginger by hand-pulling or use of a pick often leaves small rhizomes in the soil or on the surface of the ground which will resprout. In addition, manual or mechanical removal of the shoots and rhizomes stimulates seeds in the soil to germinate so that initial control is followed by a wave of seedlings. A frequently asked question is "do the roots re-sprout?" The cylindrical, flexible roots of kahili ginger will not re-sprout so these do not need to be removed. Rhizomes must be promptly carried out of the forest or composted on site. If left, they resprout within months and there is no net accomplishment except consolidation.

THE JANE WALDRON TECHNIQUE OF VIRTUOUS GINGER CONTROL: EXHAUST THE RESERVES IN RHIZOME BY REMOVING SPROUTS

Jane Waldron is an active senior (no age specified) who lives in Mauna Loa Estates. She controls ginger manually and mechanically by exhausting the plant's reserves in a determined struggle that has ended in a number of one-half acres stands of restored forest, liberated of the choking stands of wall-to-wall kahili ginger. This process can take as little as six months, if you grow impatient and uproot the weakened rhizomes from the ground. The following is her technique and prescription.

Step 1. The first step in this process is to lop off the full leafy shoots with a machete, like Jane, or with a cane knife, or loppers. You can cut these as close to the rhizome as practicable, keeping in mind that cutting into the rhizome may result in resprouting from the rhizome of that shoot. If you are careful, you can leave the leaves on the ground. There is little problem in leaving a few inches of shoot at the base so that you do not cut into the rhizome and scatter chunks that can resprout. Within several short weeks, sprouts will arise from the mats of rhizomes which hold the reserves of the plant. **Step 2.** Lop off these resprouting shoots while still small shoots without expanded leaves. Jane patrols her ginger patches about once a week to find and remove the resprouting shoots. You might be able to lengthen this return interval. However, if you let the resprouting shoots go too long and the leaves unfold and photosynthesis resumes and the rhizome's carbohydrate reserves may be replenished. This will lengthen the time needed to exhaust the reserves in the rhizomes.



Rhizomes with shoots removed. Here Jane is removing a resprouting shoot. Jane Waldron method is probably not for everybody but it works, can be carried out any time of year, and it is chemical-free.

Step 3. Continue patrolling and removing resprouting shoots for about six months. At this point the plants will be noticeably weakened. At this point, Jane uses her machete to pry the rhizomes out of the ground; you can use a pick. You can continue to cut shoots if you prefer until the rhizomes no longer resprout. The shoot and rhizome fragment should be disposed off site or composted; otherwise it will form new ginger plants.

HOW TO CONTROL KAHILI GINGER WITH HERBICIDES

A ginger rhizome prepped for spraying with herbicide. If you are using a cane knife, do not cut into the rhizomes because this disperses the ginger and each fragment created will need to be sprayed with herbicide. There is no problem in leaving short shoots which will get sprayed along with the rhizome. The shoots absorb herbicide effectively.

Use herbicides to control ginger only in the summer months, e.g., June through September. The herbicide is more effective when the plant is actively growing. First cut off the shoots at several inches up to a foot above the rhizome. Mix up a solution of Escort herbicide in water at 1 gram/liter of water. This is the highest amount allowed by the Special Local Needs Label for Hawaii http://www.cdms.net/LDat/ld5QT005.pdf). If you have a lot of rhizomes to spray, it can be hard to keep track of which clump you have sprayed already. There is a dye formulated for use with herbicides called Turf Trax Blue that will stain the rhizomes for a couple days. 24

Escort is a dry granular herbicide. Pour the granules into the special graduated cylinder provided with the herbicide package. This reads in grams, not volume measurements. Determine how many liters of water you want to fill up the back pack sprayer with and fill up the graduated cylinder with the commensurate number of grams at one gram of Escort for each liter of water in the sprayer. Spray the rhizome and the remaining shoot ends with the Escort solution.

Escort remains active in the soil for nearly a year. The advantage of this is that the seedlings that will be stimulated to germinate because the shoots of the larger plants have been cut off will take up the herbicide and be killed. Consequently, control of kahili ginger with herbicides is more thorough and long-term than manual/mechanical control. The disadvantage of using a pre-ermergent is that germinating native plant seeds may also take up Escort and be killed. Escort can be used in a similar way on other gingers in Hawai`i, but other methods may be described on the HEAR and CTAHR websites listed on the last page of the manual. Escort herbicide is a very slow acting herbicide and sprayed plants may show signs of declining, only yellowing after many months. Sometimes the sprayed rhizomes will resprout with green shoots which then yellow. The most affordable in Hilo to buy Escort is BEI on Kekuanaoa Street The active ingredient of Escort is metsulforon methyl. BEI may try to sell you Cimarron Max or Cimarron Plus with the same active ingredient plus others to act faster on ginger. Check price differences and note the Escort works just as effectively.

HOW TO CONTROL STRAWBERRY GUAVA, MANUALLY

Uprooted strawberry guava plant. This plant was horizontal and rooted at two locations along the stem..

Strawberry guava seedling hung in a tree. This technique keeps it from rerooting or re-sprouting.

**`Ōlapa seedling on left and strawberry guava on right.** One challenge with the manual removal of small strawberry guava seedlings is that they also resemble `ōhi`a and very young `ōlapa seedlings. Both `ōhi`a and guava have opposite leaves. Crush the leaves; strawberry guava smells like apple. `Ōlapa seedlings have alternate leaves and, when bigger, some teeth on the leaf margin.

Strawberry guava seedlings and saplings with single stems up to three feet tall and up to one-quarter inch in diameter can usually be uprooted. However, strawberry guava stems are typically part of a root sprouting clone, with numerous stems connected underground by a common root system. Some of the small stems of the root system can be uprooted but larger stems and roots cannot be removed this way. Uprooting stems and roots small enough to be extricated from the ground certainly reduces the vigor of the clone, even if chemical control is needed on larger stems of a root sprouting clone. However, it is prudent to cut the shoots and apply herbicide to as many stems as practicable to assure that adequate amounts of herbicide penetrate the root system of this clonal species Small numbers of uprooted stems can be hung in tree ferns or trees. If not, then they should be carried off-site or composted under black plastic similar to kahili ginger or elevated like piles of tibouchina stems because they will resprout or reroot if left on the ground.

HOW TO CONTROL STRAWBERRY GUAVA WITH HERBICIDES

Loppers work well on this size strawberry guava. There are larger loppers in the tool shed for larger plants. A saw or cane knife/machete also can be used.

Apply herbicide immediately to both cut surfaces after the cut is made. You can leave treated cut-off ends in the forest if you do. It may be better to pile them, however, to keep them drier.

Resprouting cut-stump. It probably should have been cut closer to the ground. To retreat, cut the stump again below the sprouts and apply herbicide immediately.

Immediately after cutting a stawberry guava stem as close to the ground as practicable, then immediately apply 10% Garlon 3A to the cut surface of the stump. Apply the Garlon 3A solution to the cut-off end too and pile it so that it is not lying on the ground or remove it from the forest. If you find resprouting from cut stumps, recut the stump at a lower level and immediately apply the 10% Garlon 3A.

HOW TO CONTROL TIBOUCHINA MANUALLY

Even though tibouchina rarely regenerates from seed, it is one of the most intractable and frustrating Volcano weed species to control, even with herbicides, because of the intimidatingly dense stands of large stems it forms and because of chronic resprouting from the roots. Its remarkable ability to resprout from roots and stems probably compensates for it low production of viable seed. Persistence and follow-up are the critical ingredient for successful control.

Tibouchina small enough to be uprooted by hand. Pull up the roots slowly and carefully, trying not to break larger roots because these will resprout. When you start to uproot the plant you will sense the orientation of the larger roots by the resistance. Pull in that direction rather than at right angles to minimize breakage. A few Volcano residents have been successful manually uprooting fairly large tibouchina stems. First cut them about 2-3 feet above the ground. The plants seem to weaken if left one or two weeks. Then they are uprooted by bending the knee, using the lower leg as a fulcrum, and lifting by extending the leg.

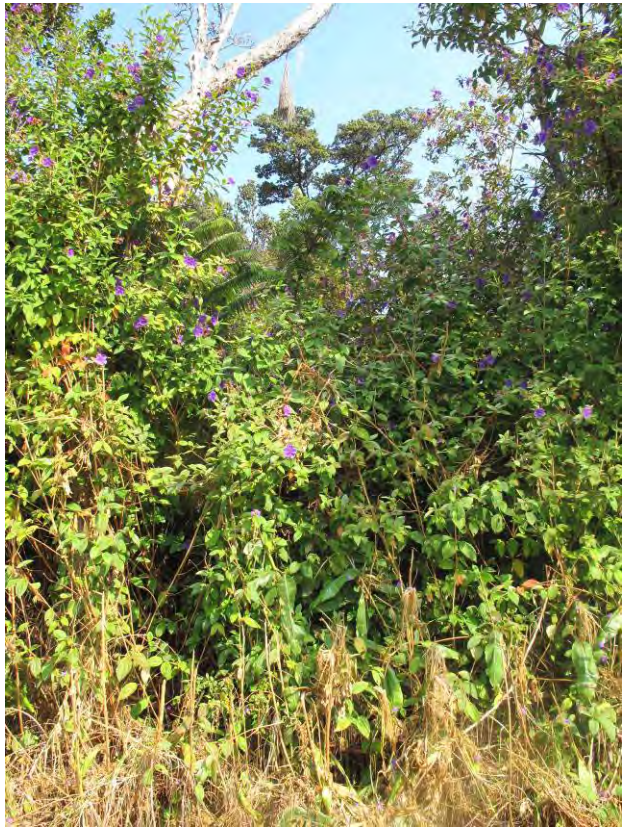
Uprooted tibouchina. Manually controlling tibouchina is an iterative process. After the first uprooting, fragments of root are often left in the soil and will resprout. It will be easier to uproot the resprouting plant if a return visit is timely; the plant and root system will be smaller. It may take three or more uprooting sessions over a few years to remove all roots from the soil with potential to resprout.

HOW TO CONTROL TIBOUCHINA WITH HERBICIDES

Cut-stump treatment of tibouchina. Cut the stem and apply 20% Crossbow in diesel. If you apply herbicide to the cut-off end after you apply it to the cut-stump, you can lay the cut-off end on the ground. This will reduce the rate of resprouting in piles. If the stump resprouts it is usually more effective to cut below the shoots and reapply the herbicide. Also fairly effective is spraying the resprouting foliage with 2% Garlon in water. Cut stump with Crossbow is effective about 50% of the time. The cut stump resprouts or the connected root resprouts after herbicide application.

Foliar treatment of Tibouchina. Foliar treatment of standing tibouchina is probably more effective than cut stump treatment. Use Garlon 4 (Remedy), 2% in water or 3% Crossbow in water. The percent kill is closer to 80 or 90% with an initial spraying. The challenge of foliar application is access, how to spray tall branches of tibouchina in dense stands. You may have to cut paths into the stands for access or incrementally treat plants on the periphery of the stands and work you way toward the interior.

COMBINE STRATEGIES WHEN “GLORY BUSH” IS IN ITS GLORY



Old growth stand of tibouchina

If you are attempting to control tibouchina in an extensive old growth stand of this species, then manual control is very difficult and chemical control is highly challenging. Old growth stands are very dense and contain many lateral stems near the ground. The most feasible first step in control may be mechanical with a small machine with a bucket or an excavator. These machines can uproot and pile the tibouchina. They inevitably leave some buried roots which will resprout (you do not want the machines to excavate too deeply when native tree roots are present). The piles of resprouting tibouchina created by machine clearing is more effectively managed when the machine operator crushes the piles. This breaks the stems into smaller branches which hold moisture less effectively and are less inclined to resprout. Another effective approach to controlling the piles of cut tibouchina shoots is to spray them with foliar spray as above. Logically, covering the piles with black plastic or a tarp should work . However, the shoots on the edge sprout laterally and emerge, even beyond a three or four foot skirting. It helps to pile the tibouchina on a platform of some kind to keep the stems off the ground and reduce resprouting.

Effectively sprayed pile of uprooted and cut tibouchina shoots.

HOW TO CONTROL HIMALAYAN RASPBERRY, MANUALLY

Himalayan raspberry, originally introduced at the Volcano Experimental Ag Station, is becoming a more widespread weed in Hawai`i. Dispersed by birds, it tends to get established in disturbed soil. If allowed to grow, these seedlings would become 8-10 foot tall spiny nightmares. Some old Himalayan raspberry nearby in the national park require chain saws to cut through the base. When the seedlings are less than 6 inches tall, you can usually find a portion of the stem near the ground (or the upper root mass) which have no or just weak spines so that they can be pulled without gloves.

A 10 inch tall seedlings of Himalayan raspberry growing in leaf litter. This plant was pull-able, even without gloves by grasping the top of the root system.

The optimal follow-up treatment for pulled seedlings. Himalayan raspberry tends to resprout from the roots when the roots are disturbed. Uprooting larger plants almost always simulates root sprouting. A prudent practice with pulling seedlings is, after the seedlings are uprooted, spray the hole containing the root remains with 10% Garlon 3A. This applies herbicide to exposed surfaces of the roots and presumably prevents sprouting from the root fragment left in the soil.

HOW TO CONTROL HIMALAYAN RASPBERRY WITH HERBICIDES

A cut Himalayan raspberry stem.

Himalayan raspberry grows most rapidly in partial shade near the forest edge or in gaps. Seedlings are most common in disturbed areas. Chemical control is the only option for larger ones. Cut as close to the ground as practicable. There are often multiple stems emerging from the soil or branching a few inches above the ground. Immediately apply 10% Garlon 3A to both cut surfaces of all the stems. Elevate the cut-off stems if possible. For foliar control, try 2% Garlon 3A.

HOW TO CONTROL FAYA TREE MANUALLY/MECHANICALLY

Faya tree is a successful invader in Volcano and some other areas of Hawai`i and can form very dense stands that eliminate almost all understory plants. Fortunately, it is a relatively easy plant to kill from seedlings to large, mature plants, with an option of manual, mechanical, and chemical methods. In some parts of Volcano Village where faya first became established in the 1950s, some very large faya trees appear to be senescing and dying. These old, weak trees do not seem to produce much fruit and can probably be allowed to die on their own. Faya tree seedlings and even large saplings can be successfully uprooted by hand; they usually do not resprout from the root system left in the ground.. However, in wet environments, uprooted trees should be hung in trees because of this possibility.

Faya tree to be treated. The small native kāwa`u (Hawaiian holly) seedlings was flagged to remind the weed controller to avoid it.

Faya tree stump covered with foil. Cut the faya tree as close to the ground as possible. Then cover with tin foil or thick black plastic to prevent successful resprouting.

HOW TO CONTROL FAYA TREE WITH HERBICIDES

Cut-stump. Faya tree is readily killed by an application of 10% Garlon 3A in water to cut stumps. Apply herbicide immediately after cutting**.** Roundup concentrate also works as a cut stump treatment but at a slightly lower rate of success and higher cost.

Old frill-girdle. Larger faya can be Controlled by girdling and applying herbicide, 50% Garlon 3A in water. Girdling should be continuous and as close to the ground as practicable. A fresh frill-girdle on faya tree is shown earlier in the manual, along with chain saw girdling.

BRIEF PROFILES OF THE ECOLOGY AND CONTROL OF SELECTED WEEDS

A number of new weeds become naturalized in Hawai`i every year. Sometimes naturalized species will spread and establish rather slowly for a number of years and then explode after decades of a quiet and harmless existence. This may be happening with knotweed and spreading selaginella in the Volcano area and beyond. One reason that weeds may become more aggressive over time is that they continue to be introduced (knotweed has been sold in seed packets for years) so that new genes flow into the populations, potentially introducing more aggressive features.

Knotweed (*Persicaria capitata*)

Ecology and control methods: First reported as naturalized in Hawai`i in 1960. Grows in a very wide range of habitats from recent lava flows to dense rain forest. Uproot and remove from site. Manual control will require multiple iterations. For chemical control use 1.5% % Crossbow in water or 2-5% Garlon 4 in water as a foliar spray. The national park is now using 2% Arsenault to control knotweed.

Spreading selaginella (*Selaginella kraussiana*)

Ecology and Control Methods: First introduced to the Kīlauea area about 70 years ago. Spreads in recently open understory of rain forest and in disturbed areas such as trail sides. Patches spread laterally by vegetative growth. Uprooting is only partially effective because of the numerous small roots along the stem; small fragments of stems left on the soil can readily take root and grow. Roundup at 1% as a foliar spray seems to be the most effective chemical control method.

BRIEF PROFILES OF THE ECOLOGY AND CONTROL OF SELECTED VOLCANO WEEDS

Florida prickly blackberry

Ecology and Control: Manual control does not work with blackberry because it will re-sprout from the roots, even at a distance from the main stems uprooted. Chemical control is the only effective method of control, even for fairly small plants. Use 0.5% Garlon 3A in water as a foliar spray in summer time. Use 10% Garlon 3A as a cut stump treatment.

Monbretia (Crocosmia)

Ecology and Control: This ornamental hybrid Is not reported to produce viable seeds but It does disperse well short distances, especially in disturbed areas. It seems like it should be controllable by manual removal since often the shoot and bulb are easily uprooted. However, uprooting often leaves behind a network of roots and small bulbs that resprout. A 1-2% solution of Crossbow in water provides fairly effective control.

English Ivy

Ecology and Control: English Ivy is planted as an ornamental and now is firmly entrenched in many trees, including native `ōhi`a, in Volcano. It also escapes into wet forest. Two percent Garlon 4 as a foliar spray is fairly effective. It is reported that you can also cut the stems near the base and apply 10% Garlon 3A to both cut surfaces. Some of the foliage can be pulled down from the tree to aid in control.

MOST GRASSES ARE FAIRLY EASY TO KILL

Many grasses can be killed by applying 1-2% Roundup as a foliar spray when the grasses are actively growing. Roundup does not work if it is raining or rains within a few hours after spraying. Sometimes a second treatment may be required, 6-8 weeks or more after the initial treatment. One problem with Roundup is that it is a non-selective herbicide and kills a broad range of plants. If you have the potential for not-target effects, then try Fusilade, which is a selective herbicide for monocots (e.g., lilies, orchids, sedges, grasses, etc). However, you might find that Fusilade is not as powerful a grass killer as Roundup and will not kill a number of grasses. If you have just a few non target plants to protect you might try a movable protective shield to keep herbicide off them while spraying grasses. Also, some grasses can be controlled effectively, with a lot of work and persistence, by uprooting, e.g., broomsedge and beardgrass (see below)

Carpet Grass

(*above)* **Two formulations of Roundup.** Both claim to be "concentrated" or "superconcentrated." However, the active ingredient, glyphosate, is 50% of the formulation on the left and just 18% of the formulation on the right. The recommendations for Roundup in this manual are based on Roundup Original with 41% glyphosate. Let's say you bought the formulation on the left with 50% active ingredient. You want to spray a 1% solution, based on a manual recommendation that is linked to the Roundup Original formulation. Intuitively, the percent solution you need will be lower than 1% since you are using a more concentrated formulation to mix up your herbicide solution. Divide 41 by 50 which equals 0.82. You need an 0.8% solution with the "superconcentrated" version of Roundup above.

DIFFICULT-TO-CONTROL GRASSES

Many grasses can be killed with 1-2% Roundup. If they do not spread by underground rhizomes, then manual control or cutting, followed by sheet mulching, might also work. Here are some tactics that work for three, harder-to-kill grasses. These approaches may also work with other grasses found to be difficult to control.

Wainaku grass

(left) Ecology and Control: Wainaku grass may be the most resistant to herbicides of all the grasses in Hawai`i. It spreads by underground rhizomes which herbicides have trouble reaching. Try an herbicide cocktail of 1% Roundup and 1% Impazypry (in Chopper, Arsenault). (see p. 24 for how to calculate percentage of active ingredient). Sheet mulching after chemical control may be "knock-out punch" needed.

Palm grass.

Ecology and Control: Mechanical control works if you are patient and persistent. It can be uprooted by hand rather easily. Haul it away so it does not resprout on site. Then come back in a few months and pull it up again; repeat three or four times. If you are not patient and persistent, try 1-2% Roundup in water as a foliar spray. Retreat 6-12 weeks after the initial treatment but make sure there is some active growth occurring for the second treatment. Another more costly but more effective herbicide is 2% Arsenal.

Ecology and Control: Uprooting and sheet mulching do not work because of spreading by underground rhizomes. Use 0.75% Roundup and wait patiently to see injury. Higher doses of Roundup are not as effective.

HOW TO CONTROL BROOMSEDGE AND BUSH BEARDGRASS

These two grasses invaded the Kīlauea summit area in the 1960's and are abundant in the Volcano Golf Course area; they can also become abundant on the wet side of Volcano after removal of uluhe or after fire. They tend to grow intermixed and look somewhat similar. Control methods are similar too. They both have a fibrous root system and can be uprooted by hand. You can use the uprooted grass to mulch the treated area. You will need mulch because the disturbance of uprooting stimulates germination of broomsedge and beard grass. In addition, invasive sedges, particularly the difficult-to-control *Cyperus brevifolius*, also invaded the site. Through persistent manual control and follow-up over several years, one Volcano Golf Course resident, Patty Kupchak, has essentially eradicated these two grasses from the `ōhi`a woodland on her property. Herbicides are less labor intensive but, since they are non-selective, will readily injure or kill native plants intermixed with the grasses. Use 1-2% Roundup. To control the sedges that invade the site after grass removal, see the control prescription for sedges (page 62).

Broomsedge. Inflorescence
Is narrow.

Bush Beardgrass. Inflorescence
flares outward at the top or is "bushy."

BAMBOOS ARE PROBABLY THE MOST DIFFICULT-TO-CONTROL GRASSES

Bamboo species are among the most difficult to control by manual/mechanical, chemical, or cultural techniques. Many species have been introduced to Hawai`i and a number of them are invasive. Partial control of two common invasive species is presented below. Black bamboo is a running bamboo, spreading fairly rapidly by spreading roots. Common bamboo is a clumping bamboo which grows in clumps from short rhizomes. Control recommendations are similar for both species: cut and treat regrowth with unspecified concentrations of a mixture of Roundup, Fusilade, and Chopper or Arsenault. Lacking specific dosage recommendation from the CTAHR and HEAR websites, you may need to experiment with doses and mixtures of herbicides. The labels for these herbicides will give information about mixing.

Black bamboo (Phyllostachys nigra)

Common bamboo (*Bambusa vulgaris*)

CONTROLLING SEDGES

Sedges are grass-like plants with triangular stems which are often found in open, disturbed areas. They can be challenging to control with herbicides. Do a foliar spray with 1% Roundup. You will find some signs or injury or decline. Wait 6-8 weeks or more and treat them again with 1% Roundup. It might be an advantage to wait on the second or third treatment to see signs of recovery and re-growth; the herbicide may be more effective when the plant is actively growing. Two of the most common small, alien invasive sedges are pictured below, along with a native sedge. Another chemical approach might be to try a cocktail of 1% Roundup and 1% Image herbicide or 1% Roundup and 1% Arsenal.

***Cyperus brevifolius*, an alien invasive sedge**

***Cyperus polystachyos*, a "weedy," that is, aggressive native sedge**

HOW TO FIND INFORMATION ON CONTROL METHODS OF OTHER WEEDS?

Probably the two most useful references for weed control methods in Hawai`i are the Hawaiian Ecosystems At Risk (HEAR) website and species profiles in Weeds of Hawaii's Pastures and Natural Areas; An Identification and Management Guide by P. Motooka, L. Castro, D. Nelson, G. Nagai, and L. Ching. ©2003, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, available on line below.

►http://hear.org/pier/commonnames/languages/English/index.html
►http://www.ctahr.hawaii.edu/invweed/weedsHi.html

Both websites list Hawaiian weed species including ecological information and control methods. The HEAR website also contain numerous links to other studies. There are also easy to find links from the HEAR website above to weed species profiles in the CTAHR website above. The HEAR website also works as a cross walk between common and scientifiic names.

Other useful references:

►Weeds of Hawaii's Pastures and Natural Areas; An Identification and Management Guide by College of Tropical Agriculture and Human Resources, 2003, by Pillip Motooka, Luisa Castro, Duane Nelson, Guy Nagai, and Lincoln Ching University of Hawaii at Manoa. 184 pp, available on-line at http://www2.ctahr.hawaii.edu/oc/freepubs/pdf/wc-8.pdf , is particularly useful for herbicide application techniques.

►http://hear.org/bibliography/byspecies/is is the bibliography of HEAR, the Hawaiian Ecosystems at Risk., by species. Also can be accessed by species from the HEAR website above.

►http://www.hear.org/starr/images/?o=plants is a huge photographic database of Hawaiian plants emphasizing invasive species identification. This website can also be a good cross walk between common names and scientific names.

►**http://manoa.hawaii.edu/hpicesu/techrep.htm**. This will lead you to the technical reports of the Pacific Cooperative Studies Unit at UH Manoa. THE DISTRIBUTION OF INVASIVE PLANT SPECIES OF CONCERN IN THE KĪLAUEA AND MAUNA LOA STRIP UNIT OF HAWAI'I VOLCANOES NATIONAL PARK, 2000-2010, by David M. Benitez, Rhonda Loh, J. Timothy Tunison[, Nicholas G. Zimmer, Jon Makaike, and Robert Mattos. This report also describes herbicidal or other control techniques by NPS employees in controlling over 130 weed species in the national park.

MAHALOS: Many thanks to Forest and Kim Starr for use of their copyright-free photographs on the HEAR website