

Establishment Protocols for 3 Native Hawaiian Plants on Roadside Areas.

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Introduction

The establishment of native Hawaiian plants along roadways in Hawaii will require a detailed analysis of the site in terms of access to irrigation water, established weeds and other ground covers as well as suitability to a mixture of desired native plants in the final landscape setting. The protocols in this document will emphasize the need for proper preplant site preparation to increase the chances of a successful establishment and long term persistence of native Hawaiian plants.

In the past, DOT plantings on the roadways have followed a pattern that has resulted in less than desirable results. The pattern, as identified by the authors, involves development of the final grade for the finished landscape that includes incorporation of various soil amendments followed by plantings with seeds, transplants or vegetative plant parts. After planting, irrigation is provided by either a temporary drip or overhead irrigation systems. Weed control and irrigation are supplied for the time interval specified in the construction contract. Once the establishment/construction phase of the contract has lapsed, irrigation is either purposefully discontinued or continues until a system failure occurs. Regardless of the circumstances, irrigation is withdrawn from the site leaving the new planting to persist with whatever natural rainfall occurs. In many cases, abrupt withdrawal of irrigation water results in the gradual decline in the vigor of planted species and the return of undesirable weeds and other adapted plant species.

This document seeks to provide protocols that start with proper preplant site preparation to purge weedy species and leave the site with a depleted capability to repopulate with undesirable vegetation. Native planting materials for roadside plantings will be identified and specific herbicides needed for a near weed free establishment protocol will be described. Following establishment, a gradual drawdown of the amount of irrigation water will be described so that roots of the planted species will be encouraged to penetrate deeper soil profiles to maintain healthy growth and retain vigor consistent with attributes of the site.

The biggest mistake with using native plants on Hawaii's roadways is to assume that native plants do not require nutrient enhancement or supplemental water to establish on these sites. This view overlooks the fact that soils along roadsides have changed so much that they are marginally suitable for growing native plants. Due to construction activity, topsoil that once supported native plants have been degraded and replaced with infertile subsoils. In addition, the construction of streets and built landscapes have also impacted the climate of the surrounding area. The reduced frequency and amount of rainfall in these areas have also changed the moisture holding capabilities of the soil.

The protocols provided in this planting handbook have been developed with the understanding that contractors have a defined time frame to finish a job and that many challenges exist in establishing a persistent landscape composed of native Hawaiian plants. Protocols described are based on research and first hand experiences of the authors. The three native Hawaiian species discussed in this report include pili grass (*Heteropogon contortus*), akiaki (*Sporobolus virginicus*) and a sedge, mauu akiaki (*Fimbristylis cymosa*).

Preplant site preparation for successful establishment of native Hawaiian plants on roadways.

This discussion on preplant site preparation will be based primarily on roadways within the H1 corridor on the island of Oahu. These sites are representative of hot, dry, low elevation sites that will be the initial locations for many new plantings of native plants in Hawaii. On many of the roadside areas on Oahu, the predominant grass species are buffel grass (*Cenchrus ciliaris*), common bermuda (*Cynodon dactylon*), guinea grass (*Megathyrsus maximus*), california grass (*Brachiaria mutica*), natal redtop (*Melinis repens*) and sour grass (*Digitaria insularis*). Broadleaf weed species that are also present in these roadside areas include koa haole (*Leucaena leucocephala*), morning glory (*Ipomoea* spp.) and creeping indigo (*Indigofera spicata*). Plantings of introduced broadleaf groundcovers such as wedelia (*Sphagne trilobata*) are also present.

There are two main categories of roadside areas targeted for native plant establishment. These are: 1) roadside right-of-ways of both newly constructed and well established corridors and 2) median strips to be replaced with new plantings. In either case the critical element will be to eliminate all existing plants (i.e. weeds) in these areas prior to re-vegetation with native Hawaiian plants. A period of no less than 6 to 9 months must be dedicated to maximize weed eradication. This provides enough time stimulate weed growth with the intent of maximizing the effectiveness of post emergence herbicides on weeds, especially perennial species. This pre-plant weed eradication program should be specified in all DOT contracts to insure that sufficient time is allotted for this essential phase of native plant establishment.

The most critical factor for achieving success in eradicating both annual and perennial weed species is water availability. The use of an automated irrigation system is essential for providing an adequate and consistent amount of water to stimulate weed growth. When post emergence systemic herbicides are applied to actively growing weeds, they are translocated throughout the plant and can kill both above and below ground parts. It is a waste of time and money to apply post emergence herbicides to plants that are not actively growing due to drought stress. They simply will not die and a repeat application will be required. Roadside landscapes without a reliable source of irrigation water should be avoided as this may not only hamper successful pre-plant weed control but also, the establishment of persistent populations of native species.

Perennial weed eradication along newly constructed roads presents unique considerations that must be addressed. The corridors along these roads represent a serious risk to erosion because soils are loose and exposed to both wind and unpredictable heavy rainfall. Weed eradication efforts on newly constructed sites should be scheduled during dry periods of the year (May to September) to minimize the chance of heavy rains. Hot weather and sufficient irrigation water will stimulate active plant growth and accelerate the perennial weed eradication process with minimal threat of rain-induced soil erosion.

It is strongly recommended that native re-vegetation sites be installed with both conventional overhead sprinklers (most likely a temporary system) and underground drip system (a permanent system with at least 8-10 years of useful function). New innovations for subsurface irrigation systems have improved the reliability and longevity drip systems for this type of water delivery system. Overhead sprinklers provide for wide coverage with easily available materials but are subject to vehicular damage and theft. A properly installed subsurface drip system may incur high initial costs but offers the potential for minimizing water use and when properly programed can encourage deep rooting of native species with reduced weed pressure.

To initiate growth/germination of annual and perennial weeds that remain after construction, both overhead and underground irrigation systems must be turned on. Water should be applied to moisten the soil to a depth of 3 to 4 inches of the soil profile. Chemical fertilizers can be applied prior to irrigation in order to enhance both weed seed germination and growth from vegetative plant parts. Once weed growth begins, a decision must be made as to when the first application of postemergence herbicide must be done. As a general rule, weeds are allowed to grow until the more aggressive ones have not yet outgrown other less vigorous weed species (about 3 to 4 weeks after irrigation). If the weeds are allowed to grow too big that they cover each other, it would be difficult to kill weeds growing in the understory. Hence, follow-up applications are required to fully eradicate all weed species. Before starting the weed eradication program, landscape contractors should both have the recommended herbicides and the properly calibrated herbicide application system ready to go so that weeds can be treated in an effective and timely manner.

In this report, trade names of herbicides will be provided as a source of information to employ the methods being described in this protocol. The use of trade names in no way represents an exclusive endorsement of products by the authors or the Hawaii Department of Transportation. Since several weed species will be present at most sites (i.e. a mixture of grass, broadleaf and possibly sedge species), a mixture of herbicides will be recommended to provide the widest spectrum of weed killing potential. All herbicides described in this protocol have a highway right-of-way or non-crop use pattern described on the product label. It is the responsibility of all herbicide applicators to follow label instructions and use these products in a manner consistent with their labeling.

The herbicides to be used in the weed eradication phase of the native plant establishment protocol are Roundup ProMax (glyphosate, Monsanto), Fusilade DX (fluazifop-P-butyl, Syngenta), Element 3A (triclopyr, Dow AgroSciences), Milestone (aminopyralid, Dow AgroSciences) and methylated seed oil (various brands referred to as MSO) as a wetting agent and plant leaf penetrant (see Table 1).

To provide consistent performance of this herbicide mixture, a spray volume delivery of 100 gallons per acre (100 GPA) is recommended. Any of the various hand-held spray devices utilized by operators should provide a uniform spray pattern with an easily controllable on/off trigger. Avoid using a sprayer that produces very small droplets that are prone to spray drift and off-site movement by wind. The sprayer must be calibrated to uniformly deliver 100 gallons of spray across an area of 1 acre (43,560 ft²) in order to effectively apply the recommended herbicides provided in this protocol.

To calibrate the spray system, the pump should operate at full power to provide good agitation in the spray tank and adequate pressure to the spray gun. This ensures delivery of a spray pattern that can cover a distance of 6-10 feet away from the applicator. In order to accurately deliver the prescribed 100 GPA, follow these steps:

- 1) Obtain a 5 gallon plastic bucket and add 294 ounces (2.3 gallons) of water. Place the bucket on a flat/level area and mark the water level on the inside or outside of the bucket using a permanent marker or a strip of duct tape. Empty the bucket and place it on a flat/level area.
- 2) Fill the spray system with water and fully power it up. Aim the nozzle/s of the sprayer system directly into the marked bucket and start spraying. Determine the time it takes to fill the bucket up to the 294 ounce mark using a stop watch. Empty the bucket and repeat this at least 3 times to insure that both the applicator and spray gun are consistent in their output for the time required to deliver 294 ounces.
- 3) Mark a test area of 1000 ft² (a suggested dimension could be 10 ft x 100 ft). With the spray system fully powered, uniformly spray water onto the marked area with just one pass. Make sure to completely spray the whole test area within the same time it took to fill the 294 ounce mark in procedure 2. Since the 1000 ft² test area was sprayed at about the same time it took to fill the 294 ounce mark in the bucket, the volume of water applied would be equivalent to 100 GPA. In order to have a consistent 100 GPA spray rate, it is necessary that the applicator must repeat/practice this procedure several times. Once the applicator has calibrated the sprayer system to deliver 100 GPA, the herbicide mixtures can be prepared. See Table 1 for the recommended products and rates.

Table 1. Recommended herbicide tank-mix rate for eliminating existing weeds prior to planting native Hawaiian plants along medians and roadside rights-of-way

Herbicide Trade Name	Active Ingredient	Amount per acre*	Sprayer applies 100 gallon/acre			Weeds controlled
			50 gallons	100 gallons	200 gallons	
Element 3A or Garlon 3A**	Triclopyr 44.4%	64 fl. oz.	32 fl oz	64 fl. oz	128 fl .oz	morning glory, plantain, wedelia
Fusilade DX	Fluazifop-p-butyl 24.5%	24 fl. oz	12 fl. oz.	24 fl. oz	48 fl. oz	guineagrass, torpedograss, bermudagrass
Milestone***	Aminopyralid 40.6%	3.5 fl. oz	1.75 fl. oz.	3.5 fl. oz	7.0 fl. oz.	horseweed, sleeping grass, spiny amaranth, clovers
Roundup ProMax	Glyphosate 48.7%	3 gal	192 fl. oz.	3 gal	6 gal	goosegrass, foxtails, castorbean.
MSO concentrate	Methylated seed oil	1.0 gal	64 fl. oz.	128 fl oz	256 fl oz.	wetting/penetrating agent

Begin the first application of the herbicide tank-mix (Table 1) to actively growing weeds at least 6-9 months before seeding or transplanting with native plants. It is important to note that Milestone should only be used during the first herbicide application. Also, Element 3A and Garlon should only be applied during the first and second applications. Element 3A and Milestone are primarily used to control broadleaf weeds. However, they can also provide control of germinating weed seeds in the soil for a period of 6 months. Due to this residual soil activity, it is not advisable to apply Element 3A and Milestone if hydroseeding/transplanting is scheduled within the next 6 months.

It is important to schedule herbicide spray applications during days with no rainfall in the forecast. Also, make sure to turn off the overhead irrigation right before spraying. Keep it turned off for at least 48 hours after herbicide application to promote herbicide action and to prevent it from being washed from the leaves. Turn on the overhead irrigation system about 2 days after the first herbicide application. Water should be applied to moisten the soil to a depth of 3 to 4 inches of the soil profile. Deep water penetration is essential to force deep-seeded weed species (e.g. morning glory) to germinate and grow so that they can be eliminated with herbicide sprays.

Herbicide treated broadleaf weeds will start to show signs of herbicide injury (e.g. water soaked leaves and down turned growing points) within a day or two. Grassy weeds will start to turn yellow within 6-10 days and should be completely dried out within 14 to 20 days.

The timing of the second spray application depends on how fast the weed population regrows after the initial herbicide application. The herbicide treated site should be regularly observed and monitored so that the second application is made before the most aggressive weeds cover the slower growing species. Under Hawaii conditions, the second application of herbicides can be done in about 6 to 8 weeks after the initial spray application. Make sure to exclude Milestone in the herbicide tank mix of the second application. Turn off the irrigation right before spraying and turn it on again after 48 hours.

Follow the steps in the second spray application (see previous paragraph) for timing a third or possibly a fourth round of herbicide application. The last spray prior to planting must exclude the use of Element 3A to avoid any possible injury due its soil active nature.

One of the most serious weedy species to be targeted during this preplant weed eradication program is common bermudagrass. Bermuda grass has been used for roadside re-vegetation in Hawaii and is present in many existing roadside plantings. Bermudagrass can emerge from seeds as well as subsurface rhizomes 4-5 months after the first herbicide application. Bermudagrass emergence and growth can be enhanced with fertilizers and consistent deep irrigation so that post emergence herbicide applications will be more effective. Of all the weeds identified in this protocol, Bermuda grass will be one of the most difficult to eradicate with this preplant weed eradication procedure.

Special considerations for preparing roadside areas with well-established stands of perennial weed species.

Oftentimes, plans call for the installation of native plants on roadside areas that are well past the newly constructed phase. Many of these sites frequently contain well-established stands of weeds such as bermudagrass, buffelgrass and/or thick stumpy patches of koa haole. Under these circumstances, it is strongly recommended that every effort is made to eradicate these perennial weeds before any soil disturbance is initiated (e.g. grubbing to remove rocks and other construction related debris).

Well-established stands of perennials such as bermudagrass have an extensive and interconnected underground mass of roots and stems. If left intact, these roots and stems can help move the applied systemic herbicides (see Table 1). This facilitates eradication since the herbicides are moved in areas of the plant that are not reached by spraying. If this intact system of roots and stems is broken up by grubbing, the ability to treat this entire mass of underground plant tissue is lost. Any sort of deep soil disturbance of an established stand of bermudagrass will turn every piece of broken root and underground stem into an independent vegetative source, capable of future weed invasion/contamination. Each and every construction specification composed by the Hawaii DOT should specifically instruct the contractor to conduct repeated herbicide applications to eliminate established stands of perennial weeds prior to any grubbing or deep soil disturbance. It is highly recommended that control of these well-established weeds be the first order of business once contracts for native plant installation are awarded and site access has been obtained. Perennial weed control efforts should make use of natural rainfall events or temporary overhead irrigation to activate growth of these established weeds. This should be immediately followed by a series of herbicide applications.

Akiaki (Sporobolus virginicus)

Akiaki (*Sporobolus virginicus*) is a rhizomatous native grass that commonly grows in mats on sand dunes and other coastal sites of the state. Various growth forms of akiaki have been observed across the state. These range from upright to turf-like. Adapted to salt and low rainfall conditions, akiaki is ideal for revegetation along coastal sites, stream banks and roadside swales. It can also be used as a salt tolerant industrial and ornamental turf.

Establishment from stem cuttings covered with hydromulch

Since akiaki produces very few viable seeds, vegetative propagation is the only feasible option for large scale plantings. In previous re-vegetation efforts, contractors have used nursery grown transplants or shallow plantings of unrooted stems for large scale plantings. Establishment from plugs is expensive and time consuming due to the costs associated with the production of nursery stock plants and hand labor needed to set plants into roadside landscapes. The preferred method for establishing large plantings of akiaki is through hydromulch capping of stem cuttings.

Re-vegetation with akiaki stem cuttings starts with the preparation of stock plants. To ensure healthy and vigorous planting materials, akiaki stock plants must be irrigated and fertilized for at least a month before harvesting the stems. Harvest planting materials a day before the hydromulch capping operation. To harvest, cut 18-24 inches of aboveground portions (i.e. stems) with a sharp hand blade or mechanized sickle bar mower. Avoid the use of line trimmers and flail type mowers as these can cause excessive damage and stress to the cuttings. Soak the freshly cut stems in a diluted Dip N Grow® root hormone solution (1:35 dilution) for a period of 24 hours in a cool shady area. To obtain a 1:35 dilution of Dip N Grow, use 2.8 gallons of Dip N Grow® and add enough water to reach a volume of 100 gallons. After soaking, drain the cuttings and keep them moist and cool, away from direct sunlight.

Prepare the planting area by eradicating the weeds with repeated applications of herbicide. Rake out dried plants and leaves as well as rocks that might interfere with rooting of the cutting. Thoroughly moisten the soil prior to planting so that irrigation applied after planting is used to primarily keep akiaki stems from drying out.

The recommended rate for planting akiaki stems is about 1100 lbs. of moist cuttings per acre or about 25 lbs. per 1000 square foot (10 ft. x 10 ft. area). It is advisable to plant in phases (i.e. plant a manageable area at a time) to efficiently utilize labor and resources as well as prevent cuttings from drying up. Plant akiaki stems by evenly spreading them on the planting surface. Make sure that the stems lay flat and are in complete contact with the soil. If stems are piled on top of each other or protruding upright, they either dry out or fail to produce roots. Good contact with the soil allows rooting to initiate in the stem's nodes. After stems are spread, apply just enough hydromulch cap to hold them firmly to the soil surface. Too thick of a hydromulch covering will exclude light that is absorbed by leaves and green stems. This results in reduced rooting and an increased time for complete cover of planted areas. The recommended rates for the components of the hydromulch cap

are as follows: 1060 lbs/acre paper mulch (Nature's Own Organic®, Hamilton Manufacturing Inc.); 966 lbs/acre straw mulch (HydroStraw® Original Mulch, HydroStraw LLC); 10 lbs/acre (C:tac, Hamilton Manufacturing Inc.), 34 lbs/acre fertilizer (22-2-9) and 100 lbs/acre Ronstar 2G (oxadiazon, Bayer Environmental Science). A 100 gallon batch (covering 650 ft.2) of hydromulch will consist of 15.7 lbs. paper mulch, 14.3 lbs. of straw mulch, 0.15 lbs of tackifier, 0.5 lbs of 22N-2P-9K fertilizer and Ronstar® 2G (the amount of Ronstar 2G added per batch is dependent upon the total area covered). It is necessary to wear personal protective equipment when handing/applying this hydromulch mixture since it contains a herbicide.

It is extremely important that irrigation levels are adjusted to keep new plantings moist during the initial phase of establishment while avoiding ponding and runoff. Once the akiaki is established (i.e. stems turn upward, roots form and penetrate the soil), irrigation levels can be reduced to allow drying of the soil surface. This can also help maintain an effective level of the applied preemergence herbicide to help control germinating weed seeds. Within the first two months of establishment, a light hand weeding should be conducted and fertilizer applied (50 lbs per acre nitrogen). After weeding, another application of Ronstar® G is recommended (100 lbs./ acre) to maintain an effective level of weed control. Post emergent herbicides can be applied after 4-5 months of growth if weeds are emerging within the Akiaki stand and complete canopy cover has not yet been obtained.

Recommendations on pre and postemergence weed control in akiaki plantings

Akiaki establishment can be severely impeded by weeds. Weeds can directly impact akiaki through competition for light, nutrients and water. They can also have an indirect impact on establishment when they are allowed to grow and proliferate. Extensive handweeding can delay the establishment akiaki since it can cause severe damage to newly rooted stems. To increase planting success and mitigate weed competition, pre-emergence herbicides must be utilized at the time of planting. Research conducted by the authors has indicated that Element® 3A, Milestone® and Speedzone® can be safely and effectively used to control broadleaf weeds in akiaki plantings. Certainty® has been observed to be safe and effective for the control of sedge weeds and selective broadleaf and grass species, see product label for details on species controlled.

Pili grass (*Heteropogon contortus*)

Pili grass (*Heteropogon contortus*) is a fire tolerant native grass that is commonly grows in clumps on the dry, leeward sides of the Hawaiian Islands. It is a culturally significant species since ancient Hawaiians used it for house construction, floor coverings and torches. Due to its drought tolerance and ability to grow in low fertility soils, piligrass has been extensively used as a restoration and erosion control species for severely degraded sites. Pili grass produces viable seed, allowing for direct seeding protocols for re-vegetation efforts. However, fresh seeds are dormant and require a postharvest storage treatment period of 3-6 months (i.e. store seeds at 86°F and 12% humidity to promote dormancy loss).

***Heteropogon contortus* (Pili grass) direct seeded establishment.**

Establishment from direct seeding

At the time that this protocol was composed, pili grass seed are in short supply and seed that is available must be used in the most efficient fashion. Pili grass establishment will proceed in 3 distinct phases: 1) establishment from seed planted along permanent drip irrigation lines and 2) fertilization and mowing to develop plant structure that maximizes seed production and produces mulch for increased irrigation efficiency and weed suppression and 3) establishment in the between row space using seed-laden mulch provided by mature plants. Research has shown that pili grass seeds are destroyed when passed through a conventional hydromulch pump. Therefore delivering viable seed by hand along the drip irrigation system is recommended.

Permanent drip irrigation lines can be set at distance of 6 to 8 feet apart. Pili grass seeds are placed directly on the drip irrigation lines at a rate of 0.5 lbs per 100 linear feet of row. Contractors need to be sure that the seeding material contains viable seeds. Since fresh seeds require a postharvest storage treatment to remove natural seed dormancy, it is very important to make sure seeds have been properly conditioned and are ready to germinate at the time of planting. A desired seeding rate should produce 2 to 4 living plants per linear foot of drip line. After pili grass seeds are installed along the drip lines, they can be held in place with a light layer of hydromulch. The recommended rates for the components of the hydromulch cap are as follows: 1060 lbs/acre paper mulch (Nature's Own Organic®, Hamilton Manufacturing Inc.); 966 lbs/acre straw mulch (HydroStraw® Original Mulch, HydroStraw LLC); 10 lbs/acre (C:tac, Hamilton Manufacturing Inc.). A 100 gallon batch of hydromulch will consist of 15.7 lbs paper mulch, 14.3 lbs of straw mulch and 0.15 lbs of tackifier and cover 650 ft. of seed row with a 1 ft. band of hydromulch.

Weed control in the between row space is very important while pili grass grows and germinates in bands along the drip irrigation lines. A convenient method of applying herbicide to this space makes use of a conventional hydromulch application system. The preemergence herbicide Ronstar WP can be added to the tank (at rate of 2.5 lbs per acre) along with a thin mix of hydromulch and tackifier (see recommended rates in the previous paragraph). The herbicide infused hydromulch is applied between the rows of newly seeded pili grass to provide control of weeds emerging from seeds. Pili grass seed

can germinate and grow in the presence of Ronstar WP if abundant overhead irrigation is supplied. If only drip irrigation is being used, contractors should be careful not to apply the herbicide/hydromulch mix on the pili grass rows. With pili grass seed in place along the drip lines and Ronstar herbicide applied to the between row space, the initial planting phase is complete. Pili grass seed will germinate in 7-10 days and grow rapidly during the summer months.

Once pili grass starts growing, fertilizer needs to be applied to stimulate rapid growth and canopy fill in along the drip irrigation rows. The objective of this phase of establishment is produce large vigorous plants that can shade out weeds and produce a large quantity of viable seeds that will be used to fill the space between the rows of drip irrigation. Fertilizer can be applied as conventional granular materials or injected via the drip irrigation system. Injecting fertilizer via the drip system offers the advantage of placing nutrients directly at the site of root absorption and in a form that can be immediately absorbed. Granular materials will remain on the soil surface until natural rain fall or overhead irrigation is applied to move nutrients into the root zone.

Once pili grass seedlings have established and growth accelerates, a mowing operation will be required to provide weed suppressing mulch around the base of plants. Mowing also increases the number of growing points from which flower spikes will emerge. Pili grass that is not mowed will grow long lush stems that tend to flop over (lodge) and form an unhealthy canopy with a limited capacity for seed production. Proper mowing will produce short bushy plants that encourage the spread of the pili grass clump. It also provides a firm base to produce seed bearing stems. If young Pili grass is mowed too closely, plants will die off and vigor of the stand will be reduced. Mowing should be planned when stems are 12 to 14 inches tall. Cut the grass to no less than 6 to 8 inches from the ground. Avoid cutting the plants lower than the recommended height since plants will have a difficult time to regrow/survive.

The type of equipment used to mow pili grass can have a significant impact on survival and desired regrowth. It is highly recommended that the mowing be done with a tool that reduces the amount of damage to soft succulent stems. Line trimmers, rotary and other cutting tools that results in ragged stem cuts should be avoided. Handheld or motorized walk-behind sickle bar mowers are the desired methods of cutting pili grass. Mowing with a motorized sickle bar encourages maximum seed production and rapid regrowth. Sickle bar mowers produce clean cuts that heal rapidly. It also stimulates bud breaks from the cut stems. A properly trimmed row of pili grass will have a stiff upright look with many new shoots emerging from the clean cut stems. This mowing operation should be employed at least 2-3 times before a seed crop is allowed to form. Clippings from the mowing operations will recycle nutrients back to the Pili grass row, improve irrigation efficiency and help to control weeds.

At 6 to 9 months, the site should have lush filled in rows of bushy pili grass with weed free areas in the between row spaces. Once this level of establishment is obtained, it is time to allow a full crop of pili grass seed to form. Flowering stems will emerge from lush bushy plants at all times of the year in Hawaii. As pili grass seeds mature, the heads will start to pull together into a twisted mass resembling the sides of a bird nest. Seeds will be fully mature once the color of the heads turns from fresh green to a dry brown mass. At this stage of seed head development, half to 1/3 of the canopy can be cut

and evenly distributed to the between row space. In this way, vigorous plants are established along the drip lines and produce a seed laden mulch that can populate the between row space.

Periodic mowing also represents the ideal time for spot treatment of weeds with herbicide sprays. Careful mowing of pili grass exposes weed growth and reduces the volume of pili grass tissue that is exposed to sprays of systemic herbicides. If possible, the delivery of seed laden pili grass mulch should occur during the hot dry months of summer (i.e. June through September). The warm dry conditions are ideal for the removal of pili grass seed dormancy.

The discussion provided here, describes three phases in the successful establishment of large plantings of pili grass. These phases include: seeding along the lines of permanent drip irrigation, development of thick bushy plants with fertilization and proper mowing, and the production of seed-laden pili grass mulch that populates the space between rows of drip irrigation.

With proper planning and an understanding of the distinct phases of pili grass establishment, contractors can make use of local environmental conditions to enhance their chances for successful weed free establishment. The rainy winter months are the time for encouraging weedy flushes in area to be planted with pili grass. Temporary overhead irrigation will greatly enhance the process of multiple weed flushes that are destroyed with herbicide applications. Seeding along the drip lines should be timed for February to April. Newly germinated plants will grow rapidly in the hot summer months. This allows the development of thick, healthy plants that recover quickly from periodic mowing and help to exclude weeds. Hot dry weather will also keep weed pressure down in the non-irrigated areas between the drip irrigation lines. The final mowing, prior to seed head formation, should be timed for September to October. Mowing at this time of the year will cause seed heads to form on short stems thus reducing the volume of seed laden mulch that needs to be spread out. Pili grass forms short stems in response to the increasingly shorter days approaching the winter solstice on or around December 22 in Hawaii. Seeds, that form in the winter months, will be mature and ready for placement to the between row spaces by April. Stems with mature seeds are cut and placed in the between row space to dry down and slowly lose their natural dormancy during the warm summer months. Once the rainy season starts, mature seeds will be able to grow and complete the coverage of the entire area.

The protocol described here is based on authors experience in growing pili grass, an appreciation of scarcity of seeds, a viable strategy for weed control, knowledge of the natural dormancy of pili grass seeds and conditions to overcome it in a natural out door environment.

Mauu akiaki (*Fimbristylis cymosa*)

Mauu akiaki (*Fimbristylis cymosa*) is a native Hawaiian sedge that commonly grows on sandy beaches and rocky outcrops along the coast. Usually found growing in clumps, this sedge possesses thick, leathery leaves and round-shaped inflorescences. Under natural growing conditions (i.e. along the coast), mauu aki aki usually grows to about 2 to 3 inches tall. Under cultivated (irrigated) conditions, it grows to about 8 inches in height. Due to its tolerance to wind and salt sprays, mauu akiaki is most suited for revegetation of coastal roadside rights-of-way. It can also be used in other areas such as median strips and other landscaped areas where permanent irrigation is installed.

Establishment from hydroseeding

Hydroseeding is generally employed for large scale revegetation of mauu akiaki since its seeds are readily germinable and extremely small (about 1 mm in diameter). Raw seed, which is composed of crushed mauu akiaki seedheads (leaves and stalks removed), is typically used for this operation. To establish mauu akiaki plantings through hydroseeding, it is important to prepare the site months in advance to remove weeds and weed seeds that could interfere with the growth of mauu akiaki. The site must be cleared of trash to ensure maximum contact of the hydroseed slurry to the soil.

The recommended rate of seeding for mauu akiaki is about 74 viable seeds per square foot or about 0.5 lbs of pure live seed per acre. Since the amount of live seed may vary from batches of raw seed, it is important to conduct a germination test for each batch. The germination test can be conducted by counting the average number of germinated seeds in each of four samples of raw seed (per seed batch). To collect samples for germination, weigh approximately 0.5 grams of raw seed from a seed batch/bag. Be sure to get raw seed from different parts of the bag to get a representative sample. Once samples have been collected, obtain 4 petri dishes (or any 3 x 3 inch shallow dish or clear container) and line them with 1 layer of paper towels. Saturate paper towels with water and sow the samples on each petri dish or clear shallow plastic food container. Be sure to spread the raw seed sample on each dish to allow maximum contact of the seeds with the wet paper towel. After sowing, cover the petri dish or container and allow the seeds to germinate under a bright window sill, away from direct sunlight. Check the containers from time to time and saturate the paper towel with water as needed. After 15 days, count and record the number of seedlings that have germinated per petri dish/container. Counting can be facilitated by using a hand-held counter. Calculate the average number of seedlings (live seed) that have germinated by adding the counts per sample and dividing the sum by 4. Use the average number of seedlings from the germination test to calculate the amount of raw seed needed to hydroseed a given area.

Sample problem: Calculate the amount of raw seed needed per acre based on seedling counts of 0.5 gram raw seed samples.

Given: Four 0.5 gram raw seed samples of mauu akiaki were germinated. Fifteen days after sowing, 319, 232, 210 and 276 seedlings were counted from samples 1, 2, 3 and 4 respectively. Calculate the

amount of raw seed needed to hydroseed an acre plot. Use the recommended rate of 74 viable seeds per square foot.

Conversion factors:

1 acre = 43,560 square feet

1 lb = 453.592 grams

First, calculate the average number live/viable seeds per gram of raw seed:

Average number of live/viable seed per 0.5 gram sample = $\frac{319+232+210+276}{4} = 259.25$ live seeds per 0.5 gram raw seed

Second, calculate the number of live seeds needed to sow an acre of land.

Number of live seeds for 1 acre = $\frac{74 \text{ live seeds}}{1 \text{ square foot}} \times \frac{43560 \text{ square foot}}{1 \text{ acre}} = 3,223,440$ live seeds per acre

Third, calculate the weight (in pounds) of raw seed needed to sow 1 acre of land. You are given the conversion of 1 pound = 453.592 gram:

= $\frac{3,223,440 \text{ seeds}}{\text{acre}} \times \frac{0.5 \text{ gram raw seed}}{259.25 \text{ seeds}} = 6,216.86$ grams of raw seed per acre.

Pounds of raw seed per acre = $6,216.86 \times \frac{1 \text{ lb}}{453.592 \text{ grams}} = 13.71$ lbs per acre

After determining the amount of raw seed needed to plant an acre, calculate the amount of paper mulch and tackifier needed to evenly distribute the seeds. For mauu akiaki, the recommended paper mulch and tackifier rates are 1,963 lbs per acre and 2 lbs per acre, respectively.

Sample problem: Calculate the amount of raw seed, paper mulch and tackifier needed to hydroseed a 5,000 square foot area. Use the calculated raw seed per acre in the previous sample problem. Also use the recommended rates of paper mulch (1,963 lbs/acre) and tackifier (2 lbs/acre).

Given:

Area to be hydroseeded: 5,000 square foot

Pounds of raw seed per acre = 13.71 lbs/acre

Recommended rate of paper mulch = 1,963 lbs/acre

Recommended rate of tackifier = 2 lbs/acre

Conversion factor:

1 acre = 43560 square feet

Calculate the amount of raw seed needed to hydroseed 5,000 square feet:

$\frac{13.71 \text{ lbs raw seed}}{1 \text{ acre}} \times \frac{1 \text{ acre}}{43,560 \text{ square feet}} \times 5,000 \text{ square feet} = 1.57$ lbs of raw seed.

Calculate the amount of paper mulch needed to hydroseed 5,000 square feet:

$$\frac{1,963 \text{ lbs paper mulch}}{1 \text{ acre}} \times \frac{1 \text{ acre}}{43,560 \text{ square feet}} \times 5,000 \text{ square feet} = 225 \text{ lbs of paper mulch.}$$

Calculate the amount of tackifier needed to hydroseed 5,000 square feet:

$$\frac{2 \text{ lbs tackifier}}{1 \text{ acre}} \times \frac{1 \text{ acre}}{43,560 \text{ square feet}} \times 5,000 \text{ square feet} = 0.23 \text{ lbs of tackifier.}$$

Depending on site conditions, the amount of mulching material and tackifier can be varied. Steeper slopes and highly erodible soils generally require more mulch and tackifier than flat areas. In order to facilitate mixing of the hydroseed slurry, it is suggested that mulching materials should first be pre-wetted in buckets. The hydroseeder should be partially filled with water and turned on while tackifier, mulch and seed are added. Make sure to add the seed last to avoid damaging the seed by the action of the pumping system. To ensure even distribution of seeds and mulch on a set area, divide the slurry into several light applications. The first light application should have covered the set area before another pass is initiated.

After hydroseeding, the planted area should be kept constantly moist for the first two months in order to provide optimum conditions for the seeds to germinate and grow. It is advisable to use an automated overhead sprinkler irrigation to provide constant and consistent soil moisture during this critical stage. In the succeeding months, supplemental irrigation should be slowly reduced until plants are fully established (~1 year after planting). Fertilize the field with 312.5 lbs complete fertilizer (16-16-16) per acre (50 lbs N per acre) six months after planting to increase growth and facilitate the establishment of mauu akiaki.

Establishment from plugs

Aside from hydroseeding, mauu akiaki can also be established using transplanted plugs grown from seed. The use of plug plants is ideal for establishing weed-free seed nurseries on plastic mulch or for establishing plantings in small pockets and areas (e.g. small planting beds and narrow median strips). To prepare plugs for transplanting, mauu akiaki seeds are first germinated in seed trays filled with potting mix and grown under regular irrigation and full sun conditions. Use about 1-2 grams of raw seed per square foot of seed tray surface area. One month after sowing, seedlings are transplanted into a multi-cell plug tray (we used 72 cell plug trays that was 13.6 x 26 inches) filled with potting mix composed of a 60:40 ratio (by volume) of potting mix (Pro-Mix 4) and black cinder. After transplanting, the seedlings are fertilized with 16-16-16 at a rate of 312.5 lbs per acre. The plugs are ready for transplanting in the field in about 3 months after growing under irrigated, full sun conditions.

The field for transplanting the plugs must be prepared months in advance to remove any weeds and weed seeds that can interfere with the growth of mauu akiaki. The site must be cleared of trash or stones to ensure a uniform planting surface. Grubbing or cultivation of the whole field is not necessary. Using a digging bar, open a slit where the plugs will be planted. The recommended spacing for planting plugs is about 4 to 6 inches on center (16 to 36 square inches per plant). Plugs can be planted at a wider spacing but fill in time will be increased with a longer sustained time frame for weed control measures to insure successful establishment.

Sample problem: Calculate the number of mauu akiaki plugs needed to plant a 5,000 square foot area. Use the recommended spacing of 4 inches on center (16 square inches per plant).

Given:

Area to be planted: 5,000 square foot

Recommended on center spacing = 4 inches = 16 square inches per plant or 9 plants per square foot.

Conversion factor:

144 square inches = 1 feet

Calculate the amount of plugs needed:

$$\frac{1 \text{ plant}}{16 \text{ square inches}} \times \frac{144 \text{ square inches}}{1 \text{ square feet}} \times 5,000 \text{ square feet} = 45,000 \text{ plants.}$$

After transplanting the plugs, the planted area should be fertilized with 312.5 lbs complete fertilizer (16-16-16) per acre (50 lbs N per acre) and kept moist for the first month to provide optimum conditions for plug establishment. An automated overhead sprinkler irrigation or subirrigation system should be used to provide constant and consistent soil moisture during this critical stage. It is also advisable to add mulch around the plugs to help retain soil moisture as well as minimize weed growth. Just make sure that the mulch does not contain weeds and weed seeds that may hinder the growth of the transplanted plugs. Supplemental irrigation should be slowly reduced 1 month after transplanting.

Recommendations on postemergence weed control of established mauu akiaki plantings

Weed control is a very important component of successful native groundcover establishment and maintenance. Post plant applications of pre- and post-emergence herbicides are important for keeping weeds in check during the establishment phase. For mauu akiaki plugs, spray applications of either Ronstar 50 WP (50% oxadiazon at 3.6 lb/acre) or Surflan AS (40% oryzalin at 58 ounces/acre) immediately after planting can provide excellent pre-emergence control of weeds. Fusilade II T&O (fluazifop-p-butyl 24% at 24 oz/acre) can provide good control of growing grassy weeds in both plug established or hydroseeded plantings. Milestone VM (40.6% aminopyralid at 7 oz/acre) can also provide good broadleaf weed control in both types of plantings. Both post-emergence herbicides can be mixed and applied as early as 28 days after hydroseeding to control both grassy and broadleaf weeds. For post-emergence sedge control, Certainty® (75% sulfosulfuron at 1.0 dry oz/a) can be applied only as a spot spray treatment in establishing plugs. Certainty is not recommended as a spot treatment in hydroseeded plantings until 6 months after planting.