TERMINATION REPORT FOR

(TA) DL2012-2

Proposal for the Development of Large Scale Seed Production and Roadside Establishment Protocol for Five Native Hawaiian Groundcovers.

PREPARED BY

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Table of Contents

Description	Page number
Executive Summary of Project Accomplishments	2-3
Establishing seed production nursery on Oahu.	4-10
Weed control research with native plants.	11-16
Seed Harvest Index for Aalii (*Dodonaea viscosa*)	17-19
Seed Harvest Index for Ahinahina (*Achyranthes splendens*)	19-23
Seed Harvest Index for Aweoweo (*Chenopodium oahuense*)	24-25
Seed Harvest Index for Ilima (*Sida fallex*)	26-27
Seed Harvest Index for Uhaloa (*Waltheria indica*)	28-30

Executive Summary of Project Accomplishments

The Hawaii Department of Transportation has provided funding in support of the research and development project titled: *"Proposal for the Development of Large Scale Seed Production and Roadside Establishment Protocol for Five Native Hawaiian Groundcovers"*. The notice to proceed date was May15, 2015 with termination date of May 15, 2018. The Task Agreement (TA) for this project is DL2012-2 with Purchase Order No. 40055133. The Cooperative Agreement number is DOT-10-030.

Summary of work performed during the project period

Establishing seed production nurseries on Oahu.

A .9 acre seed production nursery was established in the median area on the leeward side of Oahu in the Halawa interchange, see photos 1-7. All five of the project native plant species are included in this nursery. The nursery is supplied with automatic irrigation. Water conservation and clean seed collection is enhanced due to the used of durable woven black plastic ground cover used extensively throughout the planting. This covering provides for moisture conservation by reducing the evaporative effects of wind. The covering also provides for a clean non-soil surface from which seed can be collected once they are released from the plant.

Weed control research with native plants.

In addition to providing a seed production capability, the Halawa Native plant seed nursery also accommodated herbicide screening experiments. Herbicides that control weeds when germinating from seeds and existing grassy weeds that can completely cover small scrubs were evaluated for safety and effectiveness. Ronstar G (a granular formulation of oxadiazon) is applied to the ground in areas planted to small seedlings

and can control weeds establishing from seeds for up to 65 days with only slight negative impact to desired plants. Ronstar G was applied 2 times to seedling native plants, at planting and again after hand weeding 65 days later. All species studied in the project were tolerant of Ronstar G levels capable of providing over 2 months of seedling weed control. Fusilade Turf and Ornamental (T&O) is a selective herbicides that controls only emerged and actively growing grass weeds. Spray applications of Fusilade T&O were applied directly to the foliage of all project species and was found to be safe at rates effective in controlling many grassy weeds. These herbicide studies have identified safe and effective herbicides that can control weeds during the early establishment phase of native plant landscape plantings as well as grassy weeds that can invade and cover well established native plantings.

Adaption of small farm equipment for mechanical seed harvest of native plants.

The native plants included in this project were observed producing viable seed that mature at a slow and steady pace. Since all plants in this study do not have a concentrated seed production phase, it is not advisable to employ a harvest system based on a one-time collection operation. Due to their seed production systems, the recommended method of seed collection is based on multiple hand harvest events. A visual harvest index was developed for each study species to provide visual cues as to when mature seed were present in various forms of seed producing structures. These studies, to identify plant structures and conditions that contain mature viable seed, were incorporated in to the HIDOT landscape installation protocol Section 619-Planting.

Once seed bearing structures are collected and dried, small scale seed processing tools were identified and successfully employed for all species in this study. The process of seed cleaning, identified in this project, uses two commercially available machines. The first step utilizes a Westrup® LA-H brush machine fitted with a #14 mantle (1.0 x 1.0 mm square mesh) and medium nylon 0.5 mm brushes (Westrup® Inc., Plano, Texas), see Figure 2. After processing with the brush machine, pulverized seed head components can be separated with a Clipper™ Office Tester (A.T. Ferrell Company Inc., Bluffton, Indiana), see Figure 3. The Clipper Office Tester combines the use of screens and air blower to separate seed from other plant debris. These two seed processing tools were very useful in separating mature viable seed from dried plant parts for all species studied in this project.

There are no plantings of native plants used in this project located at the UH Waimanalo Experiment station. We decided to concentrate our efforts for archival plantings at the Halawa Interchange site so that at the conclusion of our work, the Department of Transportation would have a native plant resource under their direct control.

Establishing seed production nursery on Oahu.

The scope of work for this project describes a project deliverable that calls for a 5 species seed nursery at the Halawa Interchange with a total area of 0.998 acres (dimensions for planted area is 111' x 392'). In Photo 1, the location of the planted area of the seed nursery within the Halawa Interchange is provided (see black rectangle with GPS coordinates provided in the upper right hand corner). Photos 2-7 show all 5 species planted to the Halawa Seed nursery.

Photo 1. The scope of work for this project describes a project deliverable that calls for a 5 species seed nursery at the Halawa Interchange with a total area of 0.998 acres (dimensions for planted area is 111' x 392'). (GPS coordinates provided in the upper right hand corner).

Halawa Interchange Native Planting Field Site – 0.998 acres

Photo 2. Halawa seed nursery viewed from H3 off ramp looking NE toward Halawa Valley, image recorded on 12/07/17.

Photo 3. Aalii (*Dodonaea viscosa*) planting at Halawa seed nursery, image recorded 03/02/2018.

Photo 4. Ahinahina (*Achyranthes splendens*) planting at Halawa seed nursery, image recorded 12/07/2017.

Photo 5. Aweoweo (*Chenopodium oahuense*) planting at Halawa seed nursery, image recorded 12/07/2017.

Photo 6. Ilima (*Sida fallex*) planting at Halawa seed nursery, image recorded 12/07/2017.

Photo 7. Uhaloa (*Waltheria indica*) planting at Halawa seed nursery, image recorded 03/02/2018.

Weed control research with native plants.

Part of the Halawa nursery was developed as a herbicide screening facility to evaluate the response of small transplants to herbicides commonly used in newly established landscapes. In October of 2016, seedlings of 4 native species were planted to weed free experimental plots supplied with automatic overhead irrigation, see Photo 8. The ground around seedlings was exposed to the commonly used granular preemergence herbicide with trade name Ronstar G (oxadiazon, Bayer) at 100 and 200 pounds per acre. Ronstar G was applied immediately after planting and after the first manual weeding that occurred 55 days after planting. An example of the weed control (48 days after planting) obtained with the herbicide levels applied can be seen in Photo 9.

The response of weeds and native plants to Ronstar applications was measured as the time to return plots to a weed free condition, visual ratings of native plant vigor and native plant dry weight accumulation. Timed weeding allows the effectiveness of Ronstar G to be expressed as a cost to return a unit of land to a weed free condition. Assuming an employer cost of $15.00 per hour (Landscaping and Grounds keeping workers' cost based on 2016 U.S. Bureau of Labor Statistics) and the cost of Ronstar G ($83.50 per 50 pound bag quoted on 12/06/17 in Honolulu) and labor for herbicide application (2 minutes for 1000 ft^2) the cost for weed control on 1000 ft^2 conducted by a single worker was determined to be $64.50 (4 hours 20 minutes) when no herbicide was used, $13.30 (42 minutes) when 100 pounds/acre of Ronstar G was applied and $11.55 when 200 pounds/acre of Ronstar G was used. Clearly, the economic cost for weed control during the establishment of native plants, using small seedlings, can be greatly reduced when Ronstar G is applied at planting for preemergence weed control. The successful use of small seedlings, for use in roadside landscapes, helps to reduce costs since less time is need to produce a field read plant in the nursery.

Visual vigor ratings were collected from the experimental treatments 48 days after seedlings were planted and treated with Ronstar G. The data in Table 1 provides the % of maximum plant vigor visually observed for 4 native plant species in response to herbicide application.

Table 1. The percent of maximum growth vigor of 5 native Hawaiian plants in response to applications of Ronstar G herbicide. Visual rating of vigor was recorded 48 days after herbicide application. The data indicate that these 4 native plants species were not adversely affected by Ronstar G applied at either 100 or 200 pounds per acre.

Plant Species	% of Maximum Growth Vigor 48 days after herbicide application		
	untreated	Ronstar G 100 lb/a	Ronstar G 200 lb/a
A. splendens	85	91	88
C. oahuense	95	94	92
D. viscosa	97	91	93
S. fallex	94	92	88
W. Indica	97	94	69

At 293 days after planting (238 days after the second herbicide application, a representative plant from each treatment was cut at the soil surface so that dry weight accumulation, in response to herbicide treatment, could be determined, see Table 2.

Table 2. Response of dry weight accumulation of 5 native Hawaiian species to Ronstar G applications. A single representative plant was sampled 293 days after planting.

Plant Species	Dry weight (grams)		
	untreated	Ronstar G 100 lb/a	Ronstar G 200 lb/a
A. splendens	554	774	708
C. oahuense	2183	1438	1363
D. viscosa	575	646	696
S. fallex	938	1594	1142
W. indica[1]	75	137	141

1 Data for W. indica from a different experiment where dry weight accumulation of W. Indica was based on 4 plants 45 days after planting. Low weights for plants in untreated plots due to weed completion.

The dry weight accumulation data indicates that there were real differences in the amount of growth between these 5 species. A slight reduction in growth was noticeable with the use of Ronstar G at the 200 lb/a rate but not significant enough to prevent use in commercial roadside landscape plantings. We concluded that all five native Hawaii plant species can be treated with up to 200 lb/a of Ronstar G and obtain excellent weed control (for 50-65 days) and healthy landscape plants with strong normal growth.

Grassy weed control in established landscape plantings is a common and recurring problem for many groundskeepers. Fusilade Turf and Ornamental (T&O) Herbicide (fluazifop-P-butyl, Syngenta) is a selective herbicide that can kill grassy weeds, that grow around and sometimes within the canopy of broadleaf landscape plants, without harm to desired plants. Fusilade T&O was applied to 5 native plants growing at the Halawa site. The spot treatment rate for Fusilade T&O is described as .75 oz. per gallon with the addition of .5 oz. per gallon non-ionic surfactant (foliar penetration enhancer) and spray weeds to the point of complete wetting but not runoff. The non-ionic surfactant used in this test was Excel 90-NF (BEI Hawaii). Three experimental spray treatments composed of Excel 90-NF (.5 oz. /gallon) alone, .75 oz. /gallon Fusilade T&O + Excel 90-NF and 1.50 oz./gallon Fusilade T&O + Excel 90- NF were applied directly to 5 native species using an “over the top” spray to wet application on 10/19/2017, see Photo 10.

Two of the 5 species treated with Fusilade T& O, Aalii and Aweoweo, showed only slight leaf injury/leaf drop to all spray treatments. Ahinahina (*Achyranthes splendens*) responded with 5-10% leaf drop at the high level of Fusilade T&O with complete recovery in 29 days. Ilima lost 75-95% of its treated foliage (low and high rate of Fusilade T&O, respectively) at 18 days after treatment. However, a surprising full recovery of the Ilima foliage was observed at 62 days after spray application; see photo 11 a-c. Uhaloa (*Waltheria indica*) showed little to no leaf drop in response to spray application but did respond with 20-40% (low and high rate of Fusilade T&O, respectively) of the treated foliage showing necrotic leaf spots 12 days after spray application. Full recovery with normal foliage was observed within 3 weeks after spray application. These results indicate that Ronstar G and Fusilade T&O Herbicide are safe and effective tools for early establishment and long term maintenance weed control in all five native plant species included in this project.

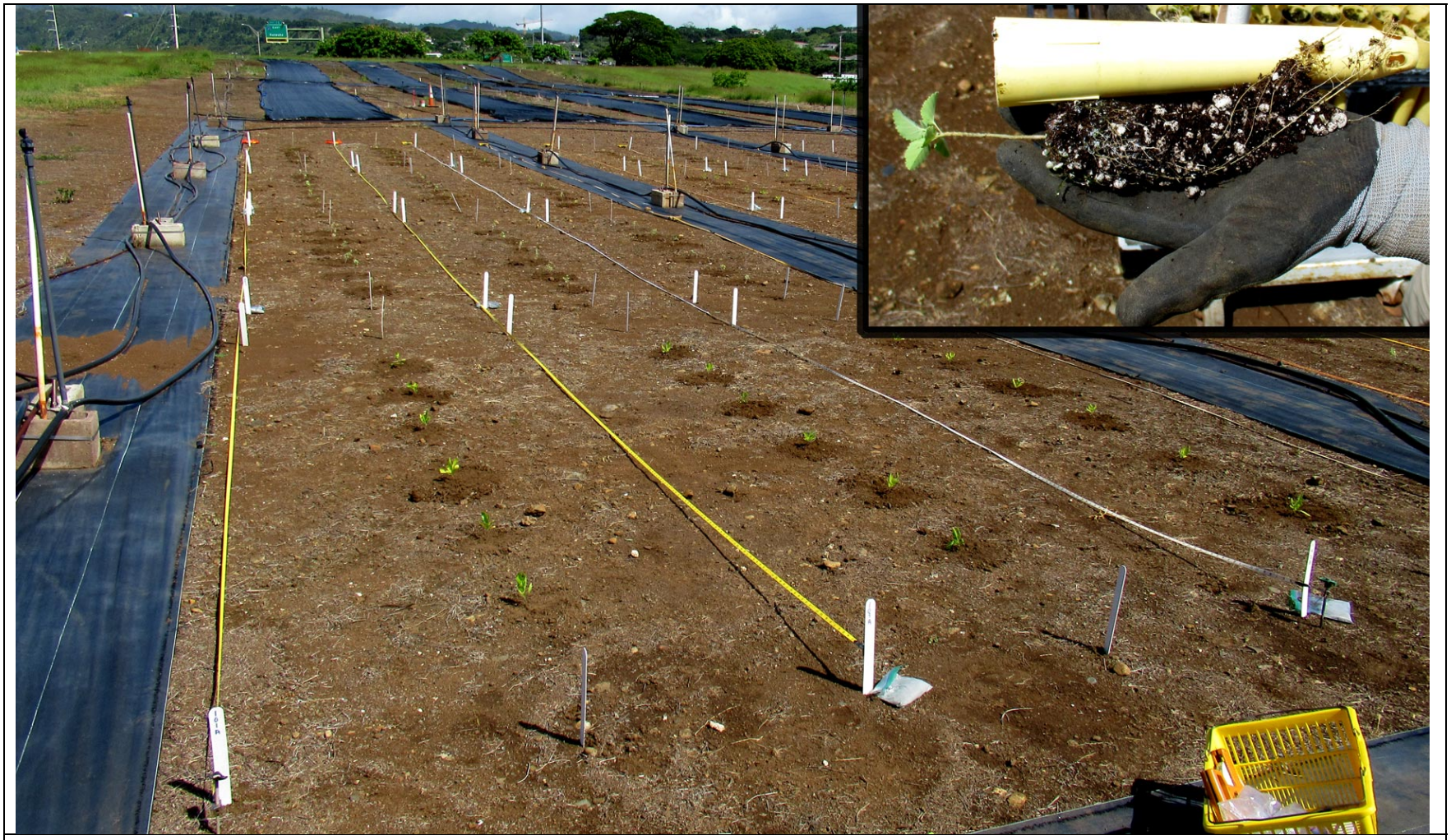


Photo 8. Small seedlings are transplanted from yellow dibble tubes into herbicide screening plots at Halawa Seed Production Nursery. Image recorded 10/16/2016.

Photo 9. Aali'i (*Dodonaea viscosa*) seedling and weed response to Ronstar G treatments at 48 days after planting. Aali'i appears unaffected by Ronstar G applications. Image recorded 12/03/2016.

Photo 10. Graduate student Alex (AJ) Lindsey applying a spray to wet application to Uhaloa plants to test tolerance to an "over the top" application Fusilade T&O Herbicide. Image recorded 10/19/2017.

	Photo 11a. Ilima prior to spray application of Fusilade T&O at .5 oz. /gallon. (image recorded 10/19/17)
	Photo 11b. Ilima showing 35% leaf drop 8 days after spray with Fusilade T&O at .5 oz. /gal. (image recorded 10/27/17
	Photo 11c. Ilima showing full foliar recovery 62 days after spray with Fusilade T&O at .5 oz./gal. (image recorded 12/20/17)

Development of visual seed harvest indicators for 5 native plant species.

Included in this termination report are detailed visual seed harvest indicators for Aalii (*Dodonaea viscosa*), Ahinahina (*Achyranthes splendens*), Aweoweo (*Chenopodium oahuense*), Ilima (*Sida fallex*) and Uhaloa (*Waltheria indica*).

Seed harvest index for Aalii (*Dodonea viscosa*).

Aalii seed are produced in a 4-winged seed capsule. The seed capsule present clusters that change color and texture as seed mature from fresh bright red tissue to dry and brown. The dried brown capsule is the only stage of development where round black seed, capable of germinating to produce seedlings, can be collected. The sequence of immature reddish colored capsule with immature seed to the dried brown capsule with mature seed is presented in Photos 12 a-c. Seed germination studies demonstrated that only the dark black seeds are mature and viable for seedling production.

Many times, native plant seeds possess a form of physical dormancy imposed by a hard seed coat. The hard seed coat can prevents germination until mechanical or biological processes compromise the seed's outer covering allowing for oxygen and water to enter and initiate germination. A seed scarification experiment was conducted on Aalii seeds that were extracted from the dry husk stage of the seed capsule. Seed scarification was evaluated using a commercially available mechanical sandpaper scarifier. Scarification was conducted in a Forsberg seed scarifier with a 1/3 horsepower electric motor (Forsberg, INC., Thief River Falls, MN, see photo 13 a). With the Forsberg scarifier, seeds are placed in round cylinder with rotating metal impellers. The spinning action of the impellers rolls the seed against the cylinder walls covered with sandpaper. The movement of the seeds against the sandpaper provides a controlled and repeatable method of seed scarification. Sandpaper coarseness is classified with a CAMI grit designation. The 80, 60 and 40 grits utilized have average particle diameters of 190 µm, 265 µm and 425 µm, respectively. The seed scarification experiment evaluated the 80 grit sand paper with three exposure times of 0, 15, 30 seconds. See photo 13 b for results of scarification experiment. Aalii seed showed a slight increase in germination with both 15 and 30 second scarification exposure to 80 grit sandpaper.

	Photo 12 a. Aalii flowers and 4-winged seed capsule cluster with reddish color. No mature seed at this stage
	Photo 12 b. A'ali'i's dried brown seed capsules containing mature viable seed
	Photo 12 c. Immature seeds from reddish seed capsule on the left. Dried brown seed capsules on the left contain mature black seeds that can germinate to produce seedlings

	Photo 13 a. Forsberg seed scarifier with a 1/3 horsepower electric motor with metal impellers to rotate seed against 80 grit sandpaper to compromise seed outer coating and allow for germination
	Photo 13 b. Aalii seed scarification germination test determined if fresh seed possess physical dormancy. Representative results from left to right are: 0, 15 & 30 seconds of exposure to 80 grit sand paper in Forsberg seed scarifier. Results indicate that Aalii seed germination is improved with short term exposure to mechanical seed scarification.

Seed Harvest Index for Ahinahina, (Acharanthus *splendens).*

Ahinahina (AS) was planted as seedlings into a replicated Ronstar G tolerance study on 10/01/2016. On 02/02/18 (389 days after planting) seed heads were collected that represent 5 distinct stages of seed head development. The seed head stages were separated into categories that reflect visual attributes related to viable seed production. See Table 3 for a description of the 5 stages of seed head development and Photo 14 for the corresponding images of the verbal descriptions.

Table 3. Five stages of AS seed head development.

Stage	Description of flower spike development stages related to viable seed production.
1	No opened flowers on spike, florets with 90 degree angle from main flower spike.
2	Previously open flower buds 25% of total flower spike, florets with 100 degree angle from main flower spike.
3	Previously open flower buds 50% of total flower spike florets with 130 degree angle from main flower spike.
4	Previously open flower buds 75% of total flower spike, florets with 135 degree angle from main flower spike.
5	Previously open flower buds 90% of total flower spike, florets with 160 degree angle from main flower spike and 5-10% of loss of seed bearing capsules at the bottom of the stalk.

Seed heads were placed in paper bags and dried for 6 days at 43 degrees Celsius (110 degrees Fahrenheit). Dried seed heads were processed with a brush machine to fracture dried seed head tissues and release dry viable seed, see Photos 15. A mixture of seed and fracture seed head debris was separated into .2 gram portions and applied to the surface of media filled cells of a preformed vegetable transplant production tray. Seeds and related plant debris was lightly covered with a thin layer of additional soilless media. Trays were set on outdoor benches and were watered 3 times daily for 2 minutes to provide for maximum seed germination. At 54 days after planting on 04/03/18 the seedling counts of AS seedlings were recorded.

Results

See Table 4, bottom row for number of seedlings germinating from a specific seed head stage of development. The data indicate that that viable seed germination begins at stage 4 and is highest at stage 5. Seed collectors should monitor seed head development and begin to collect heads when the bottom 2-3% of the seed brackets is just beginning to fall off.

Photo 14. Five stages of AS seed head development. The least mature seed head (stage 1) on the left side with the most mature seed head on the far right side (stage 5). Loss of mature seed at the bottom of the seed spike and a downward angle between the seed stalk and seed containing capsule are an indication of viable seed production. White line indicates last opened flower bud, all buds lower than these points have opened and if pollinated are forming seeds.

Table 4. Close-up images of the 5 AS stages of flower spike development and the number of seedlings produced from 0.2 grams of a combination of dried seed head debris and seeds see bottom row for seedling counts.

Stage 1	Stage 2	Stage 3	Stage 4	Sage 5
# of seedlings per cell				
0	0	0	1	5

Photo 15. Processing of AS dried seed heads begins with fracturing with a brush machine, top image. The mixture of dried seed head debris and seeds are separated with a seed cleaning device to yield a much cleaner seed mixture, see inset of middle image. An equal weight of seed and dried seed head debris (0.2 grams) is applied to the surface of media filled vegetable transplant cells to determine the presence of viable AS seeds, see bottom image.

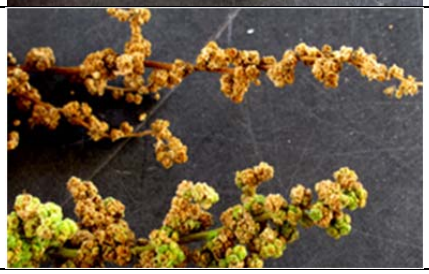
Seed Harvest Index for *Chenopodium oahuense*.

Aweoweo (*Chenopodium oahuense*, CO) plants from the Ronstar tolerance test were used to recover flower spikes of increasing degree of seed maturity development on 11/17/2017. Six categories of flower spike development were characterized, see Table 5. Intact seed heads were dried in a forced air oven for 17 days at 43 degrees Celsius (110 degrees Fahrenheit) prior to the start of the seed germination study. Dried flower spikes were removed from the dryer and then seed capsules removed from spikes and fractured with the brush machine. Additional flower spike debris was removed from seed capsules by passing through a series of screen using the Clipper Office Tester. A combination of fractured dried seed capsules and seed were weighted out in 0.2 gram aliquots and used to seed vegetable seedling tray cells filled with ProMix 4 potting media. The seed germination experiment contained 6 treatments that were correlated to the previously identified six flower spike development stages. A mixture of seed and fractured seed head debris was applied to the surface of plant cells in a replicated study. Seeded trays were placed on outdoor benches on 12/04/17 and were received 2 cycles of overhead irrigation daily. Counts of seedlings in each treatment were recorded on 01/30/2018, 57 days after the start of the experiment.

Results

The seed germination data indicated that the highest level of viable seed were found from seed heads in the #6 maturity category with the next highest level of viable seed found in category #5, see Table 5. To obtain the highest level of viable seed, Aweoweo collections should be restricted to dry seed heads where some bud drop is just beginning at the bottom of the seed production stalk. Seed heads showing green color should be avoided as these will have little to no viable seeds present.

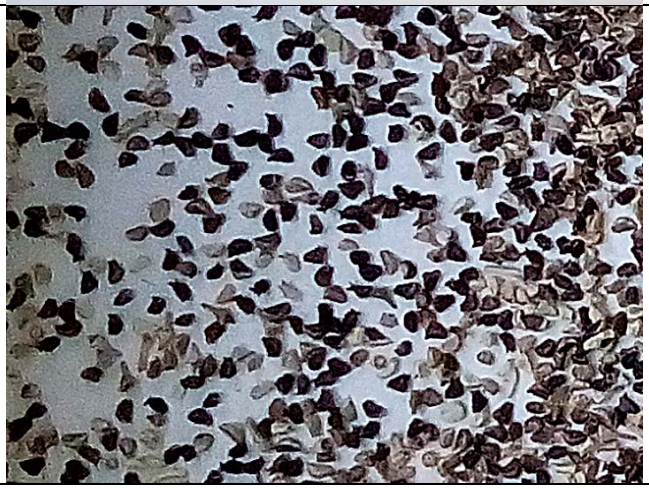
Table 5. Chenopodium flower spiked development and viable seed production indicated by seedlings growing from direct seeded cells.

Flower spike description	Flower spike image	# of seedlings per cell
1. 100% Small green flower buds on flower spike, just emerging from leaf axis. Bud attachment to spiket visible with clear space between buds.		0
2. 100% green buds with swelling to oval shape. Space between buds filled due to swelling.		0
3. 100% green buds with anthers visible at the ends of spikets. Buds on spiket touching due to swelling		0
4. 85% dark green 15-20% turning pale green. No bud drop due maturing tissues.		1
5. 60% dark green buds, 30-40% pale green buds & 15-30% brown buds with, no bud drop from spikets.		5
6. 15-25% pale green buds with 75-85% brown with 5% bud drop		14

Seed Harvest index for Ilima (*Sida fallex*)

Mature Ilima (*Sida fallex*, SF) plants at the Halawa seed nursery, planted in October 2016 site began flowering at the beginning of February in 2018. Ilima flowers form at the tip of branches and as the branch grows new flowers are added. So at any time during seed collection events, mature seed can be found in open dried seed capsules towards the inside of the canopy with increasing less mature seed formed towards the outside of the canopy. This staggered form of seed development requires multiple hand harvest operations to collect mature seed while allowing unopened capsules a chance to produce seed. Once the Ilima seed capsule opens, dry mature seed tend to drop from the plant over a 4 month period. In order to collect the maximum amount of seed from a nursery style planting, it would be best to let seed mature and fall to a synthetic ground cover located below the plants. Once seed production ends, around the 1st of July, plant stems can be cut back and the mass of leaves and seed collected with a field vacuum device. The mass of leaves and seeds should be slowly air dried in a covered open-air structure. Forced air drying is not recommended for Ilima seed. It has been the experiences of the author of this report that mechanical forced air drying, for a little as 10 days at 100 degrees Fahrenheit, will result in a form of physical dormancy or death that prevents seed from readily germinating.

Mature Ilima seed are contained in seed capsules that split open to reveal a circular set of angular dark brown seeds. The images in Photo 16 a-c show the progression from open Ilima flowers to mature seed in opened dried capsule. A seed scarification experiment was conducted on Ilima seed that were extracted from the dry opened seed capsule that were harvested on 06/04/18. Seed bearing Ilima stems were cut from plants and dried in a shaded glass house for 14 days. Dried leaves, small stems and seed capsules were processed with the brush machine and Seed Tester. The need for seed scarification to allow for germination was evaluated using a commercially available mechanical sandpaper scarifier. Scarification was conducted in a Forsberg seed scarifier with a 1/3 horsepower electric motor (Forsberg, INC., Thief River Falls, MN, see photo 13 a). With the Forsberg scarifier, seeds are placed in round cylinder with rotating metal impellers. The spinning action of the impellers rolls the seed against the cylinder walls covered with sandpaper. The movement of the seeds against the sandpaper provides a controlled and repeatable method of seed scarification. The seed scarification experiment evaluated the 80 grit sand paper with three exposure times of 0, 15, 30 seconds. The results of this experiment indicated that physical dormancy may not be the only form of seed dormancy employed by Ilima seed. The research conducted on Ilima seed, during this project period, did not produce a reliable method of post-harvest seed treatment for the production of seedlings from freshly harvested seed.

	Photo 16 a. Ilima flowering branch with outer portion of canopy on the left and inner portion of the canopy to the right. First formed flowers appear towards the inside of the canopy with new unopened flower buds at the tip of the branch.
	Photo 16 b. Opened Ilima flower at the left, pollenated flower with collapsed petals at the center and opened seed capsule with a circular row of mature dark colored seed at the right.
	**Photo 16 c**. Close-up of Ilima seed separated from dried leaves and seed capsules. Mature seed are dark and sharply angular.

Seed Harvest Index for Uhaloa (*Waltheria indica).*

Waltheria indica transplants were installed to field plots in December 2013 at a roadside demonstration site located in Honolulu Hawaii. Utilizing discrete visual cues to characterize seed head or fruit maturity can be a reliable indicator of the optimal time to harvest seed. Flower clusters of *W. indica* were separated in to six categories (CATs) based on visually distinct attributes of development (Figure 1). CAT 1 was visually identified as pre-flowering, where no flower buds were open, with 100% green tissue. CAT 2 consisted of open flower buds with approximately 10% senescing flowers with 100% green flower cluster tissue. CAT 3 was identified by 40-50% senesced flowers with 10% necrotic flower cluster tissue. CAT 4, 5 and 6 were identified by 50%, 75% and 100% necrotic flower cluster tissue, respectively.

On a representative 17-month old (4 months for transplant production and 13 months in the ground) *W. indica* plant with a 1.5 meters long side branch, a visual approximation of the percentage composition of each flowering CAT is: 1% CAT 1, 5% CAT 2, 30% CAT 3, 30% CAT 4, 30% CAT 5, and 4% CAT 6. The significantly highest mature seed content was extracted from the CAT 3 with a mean seed yield of 3.28 grams (table 6). The 4th and 5th CATs resulted in the next highest yield of 2.73 and 2.81 grams of seed, respectively. No mature seed was found in the CAT 1 and only 0.57 grams in CAT 2. The fully senesced CAT 6 contained 2.17 grams of seed. The utilization of this seed harvest index can aid decision making for seed harvesting from wild population allowing for an immediate assessment of harvest timing while in the field. Harvest practitioners assessing *W. indica* seed maturity can follow the color indicator swatch to compare CAT development and subsequent seed maturity. Understanding that optimum seed harvest timing for *W. indica* can be achieved at color CAT 3 can aid in harvest and management decisions.

It was determined that Uhaloa seeds have a physical dormancy that provides on 3-5% germination for fresh dried seed. The greatest dormancy relief (most germination) was achieved with the mechanical electric drum scarifier lined (see Photo 13a) with 80 grit sandpaper a 30 seconds.

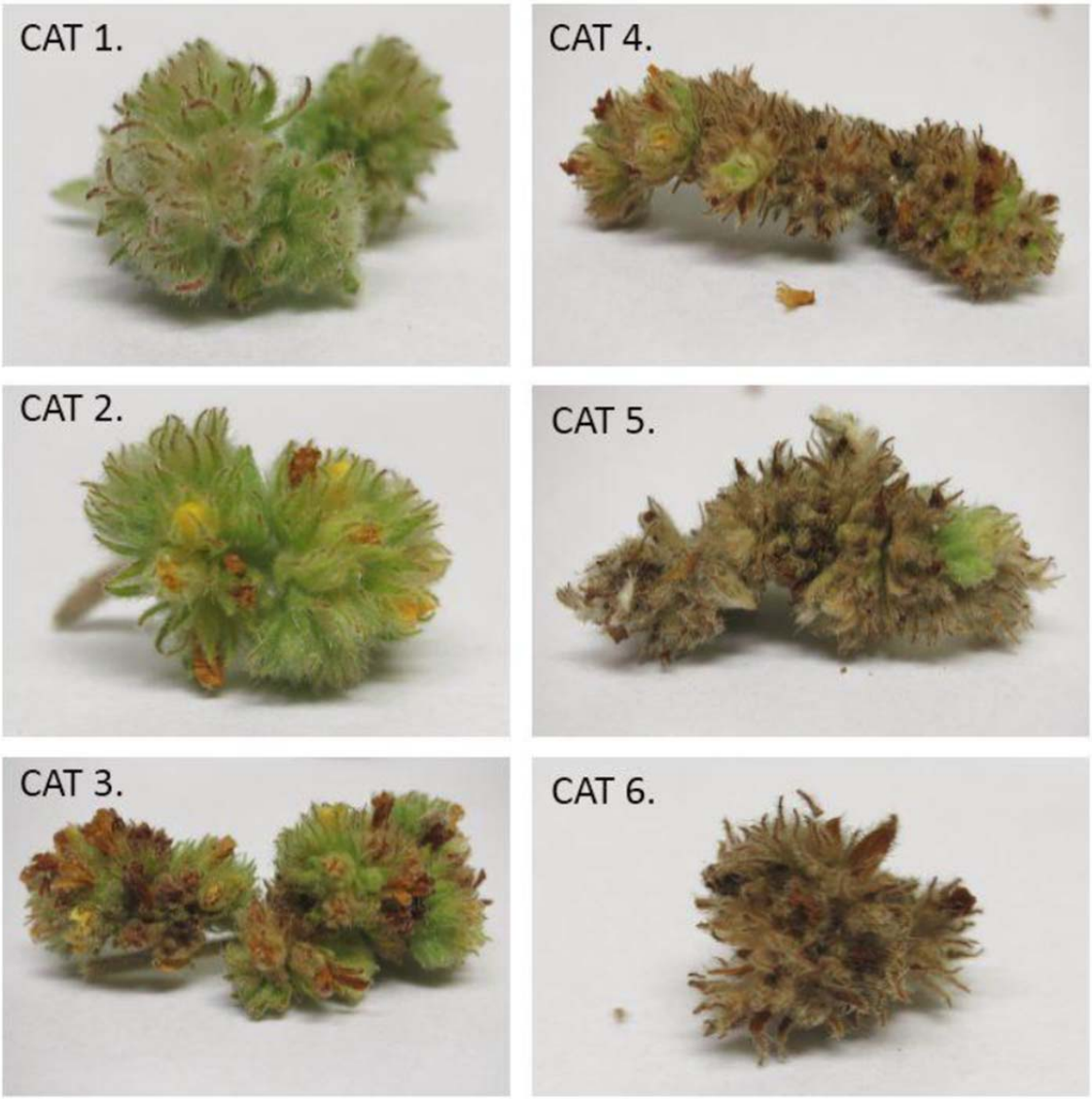


Figure 1. Six Waltheria indica flower cluster CATs used for determination of seed harvest timing visual indicators. CATs were classified from immature to mature (CAT 1 to 6, respectively) by presence of flowers, senesced flowers, green tissue and necrotic tissue.

Seed yield *W. indica* based on seed cluster maturity category	
Category	Seed yield (g)
1	0.0
2	0.57
3	3.28
4	2.73
5	2.81
6	2.17

Table 6. Table of seed yield means and percent for W. indica classified over six visual color CATs of flower head clusters.

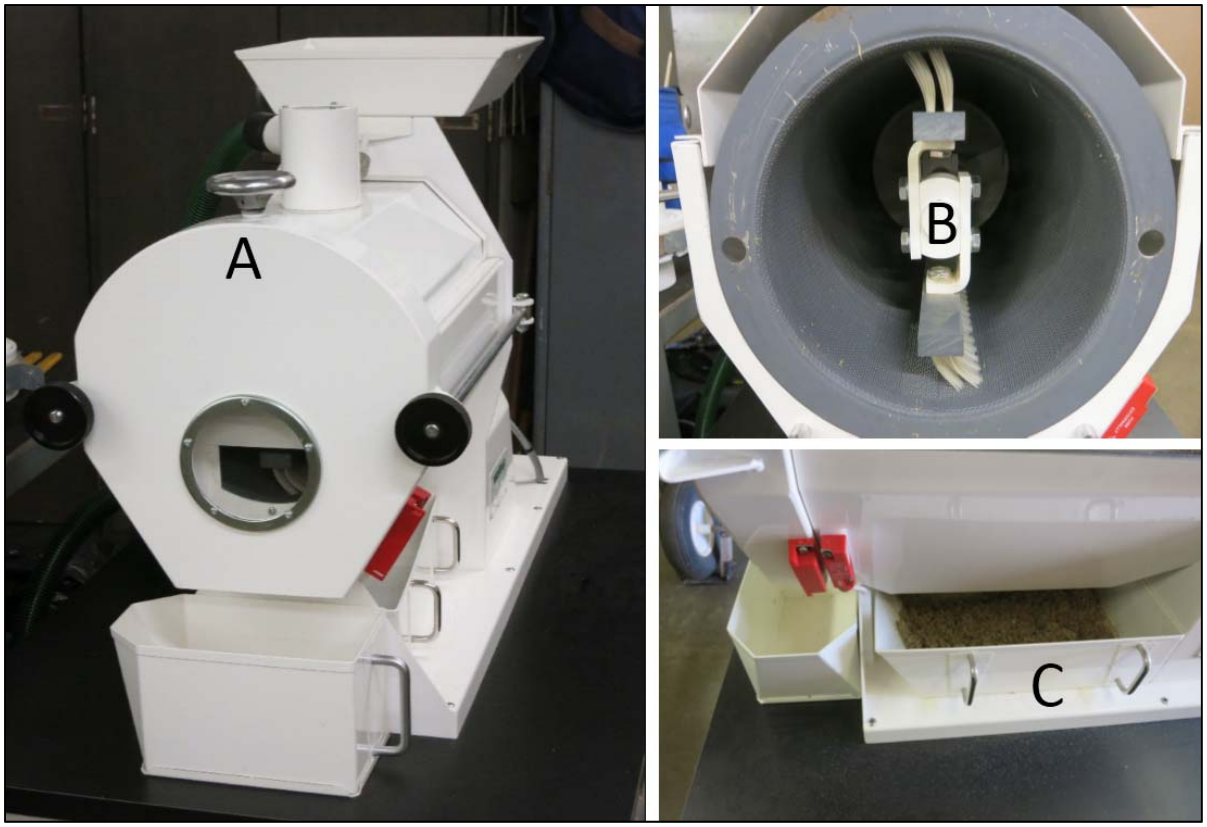


Figure 2. Westrup LA-H brush machine is used for the first seed cleaning stage to separate seeds from seed heads. Very find debris and small seed pass through the perforated cylinder and are collected in C) Catch pan at bottom of machine. Seed too large to pass through the perforated cylinder are pushed by the rotating brushes to the opening below cover A. Seed containing mixture of then processed by the Clipper Office Tester, see figure 3 below.

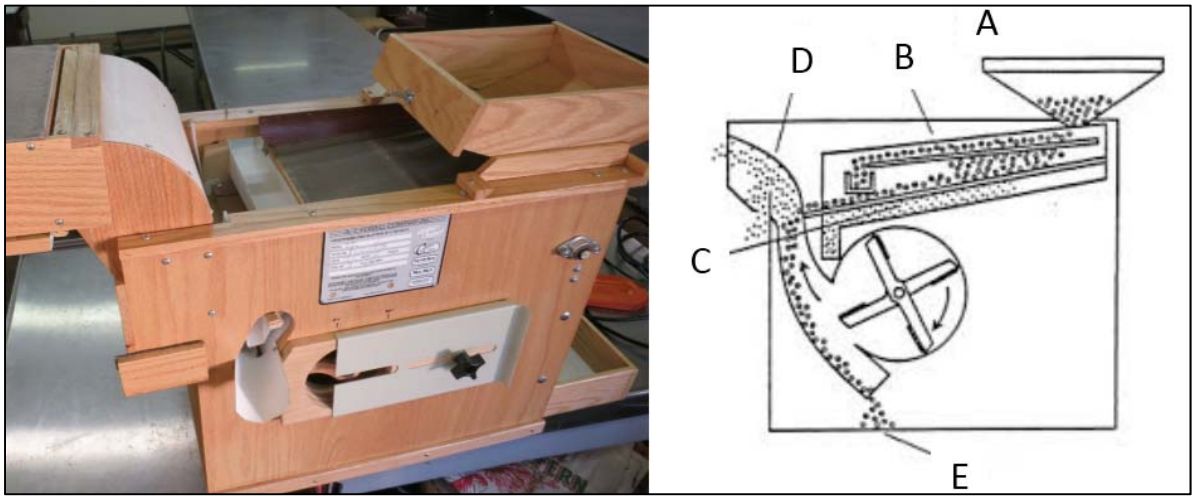


Figure 3. The second stage of seed cleaning is accomplished using a Clipper Office Tester machine. The right diagram indicates the seed path within the machine. A) The hopper into which bulk material produced from the Westrup brush machine can be placed. Screens and adjustments to the wind blast control the separation of seed and non-seed plant debris.