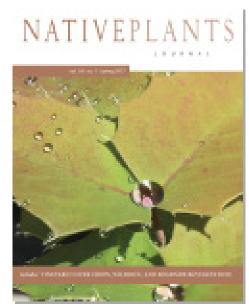
Evaluation of 3 hydromulch planting techniques for establishing *Fimbristylis cymosa* (mau‘u ‘aki‘aki), a native Hawaiian coastal sedge with roadside revegetation and landscape ground cover potential



Orville C Baldos, Joseph DeFrank, Scott B Lukas

Native Plants Journal, Volume 18, Number 1, Spring 2017, pp. 20-31 (Article)

Published by University of Wisconsin Press

Field planting of *Fimbristylis cymosa* R. Br. (Cyperaceae) for seed production.

Evaluation of 3 hydromulch planting techniques for establishing *Fimbristylis cymosa* (mauʻu ʻakiʻaki), a native Hawaiian coastal sedge with roadside revegetation and landscape ground cover potential

Orville C Baldos, Joseph DeFrank, and Scott B Lukas

ABSTRACT

Three hydromulch planting techniques (hydroseeding, hydromulch capping of seedlings, and hydroplanting of seedlings) for *Fimbristylis cymosa* R. Br. (mauʻu ʻakiʻaki; Cyperaceae) were evaluated on compost-filled plots for the first 6 mo of planting. Hydroseeding comprised spraying a seed–mulch slurry at a rate of 437 live seeds/m^2 (41 seeds/ft^2) and 2200 kg/ha (1963 lb/ac) paper/straw mulch. Hydromulch capped seedlings comprised applying seedlings by hand to the surface at a rate of 199 plants/m^2 (18 plants/ft^2) and covering them with mulch at a rate of 4400 kg/ha (3926 lb/ac). Hydroplanted seedlings comprised spraying a seedling–mulch slurry at 199 plants/m^2 (18 plants/ft^2) with a mulch rate of 4400 kg/ha (3926 lb/ac). Hydroseeded plots attained the highest plant counts and exhibited the same monthly percent visual cover as hydromulch capped seedlings. Hydromulch capping of seedlings is a less-efficient planting method, as it required more time and resources for seedling preparation compared to hydroseeding. Results of the study support the recommendation of hydroseeding for large-scale planting and establishment of *F. cymosa*.

Baldos OC, DeFrank J, Lukas SB. 2017. Evaluation of 3 hydromulch planting techniques for establishing *Fimbristylis cymosa* (mauʻu ʻakiʻaki), a native Hawaiian coastal sedge with roadside revegetation and landscape ground cover potential. Native Plants Journal 18(1):20–31.

KEY WORDS
environmental horticulture, hydroseeding, native species revegetation, Cyperaceae

NOMENCLATURE
USDA NRCS (2017)

Photos by Orville C Baldos unless otherwise noted.

The use of native species in roadside revegetation has greatly increased over the past 20 y because of growing environmental awareness, recent plant material availability, and active promotion by the Federal Highway Administration (Knapp and Rice 1994; Harper-Lore 1996; Steinfeld and others 2007). In Hawaii, roadside revegetation with native plants is relatively new and is progressively gaining interest. Studies are currently underway on seed production, roadside establishment, and roadside maintenance techniques for a number of Hawaiian ground cover and shrub species. Over the next 20 y, the demand for native Hawaiian plants in roadside revegetation and urban landscaping is expected to increase because of the enactment of HB206/SB435, a state bill that requires increased use of indigenous and Polynesian-introduced plants in new and renovated publicly funded landscaping projects (OHA 2015).

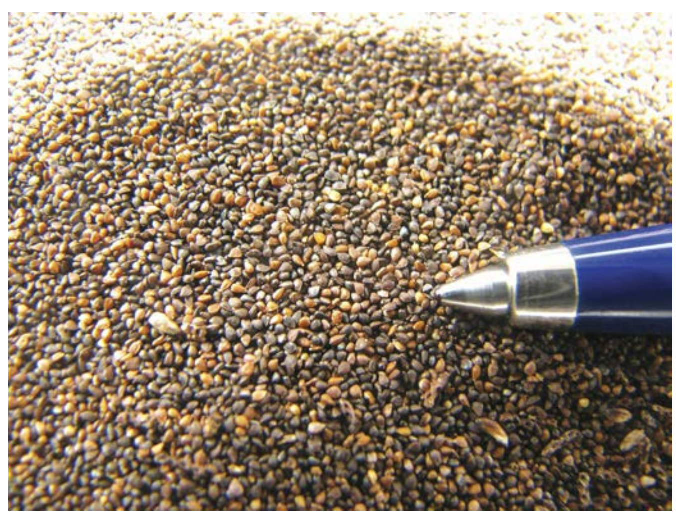
Successful roadside revegetation with native plants requires efficient large-scale propagation and establishment techniques. Hydromulch planting is a well-established method for large-scale revegetation of roadsides. It was first developed in 1938 by the Connecticut State Highway Department as a means to plant difficult sites, such as steep slopes and other roadside areas (Button 1966; Pill and Nesnow 1999). Today, hydromulch planting goes beyond revegetation of steep slopes. It has been widely accepted and used for establishing turf in residential and other high-value landscapes (Pill and Nesnow 1999) and has also found applications in green roofs (Spall 1998).

Hydromulch planting makes use of a water carrier to apply seeds or vegetative plant propagules through a pump, delivering them by using a nozzle (Beard 1973). The system is generally composed of a large tank (378–6057 l [100–1600 gal]) connected to a pump, which provides hydraulic agitation and applies the seed–water mixture through a hose with a nozzle attachment (Steinfeld and others 2007). Aside from applying the basic seed and water mixture (hydroseeding), hydromulch planting mixes also contain mulch made of wood fiber (Emanual 1976), recycled paper or straw, fertilizer, biostimulants (Landis and others 2005; Steinfeld and others 2007), and herbicides (Lukas and others 2015). If the hydroplanting operation involves the application of vegetative plant parts, such as grass sprigs or rhizomes, the process is called hydrosprigging (Mellon 1989). Hydromulch planting operations in Hawaii are done mainly for erosion control purposes and for establishing turf in high-value areas such as golf courses, resorts, and residential lots. Commonly used species have primarily been nonnative, fast-growing grasses.

Fimbristylis cymosa R. Br. (Cyperaceae) (common names: mauʻu ʻakiʻaki, tropical fimbry, and hurricanegrass) is a low-growing coastal sedge that is native to the main Hawaiian Islands and across the Pacific Basin (Wagner and others 1999). Tolerance to salt, wind, and drought, coupled with an unusual leaf texture and dwarf growth form make it a highly desired ornamental species (Baldos and others 2012). Propagation of this species is easy using seeds or division of clumps. Because of these characteristics, *F. cymosa* is a recommended native ground cover for use in landscapes (Tamimi 1999) as well as for riparian restoration (Crago and others 2004). In addition to these applications, interest has increased in its potential use in roadside revegetation (Anonymous 2009).

To efficiently utilize *F. cymosa* for roadside revegetation applications, studies are necessary to assess its compatibility with hydromulch planting methods. In this study, we evaluate the efficacy of 3 hydromulch planting techniques (hydromulch capping of seedlings, hydroseeding, and hydroplanting of seedlings) in terms of plant counts per meter squared and percent coverage over a 6-mo establishment period.

Close-up of *F. cymosa* seedlings capped with hydromulch.



Close-up of *F. cymosa* seeds.

MATERIALS AND METHODS

Planting Material and Seed Source Establishment

Stock plants of *F. cymosa* (HA#5866, 9079806) were sourced from the USDA Natural Resource Conservation Service (NRCS) Hoʻolehua Plant Materials Center in Molokaʻi. In June 2006, a soilless nursery was constructed at the University of Hawaii Magoon Research and Instructional Facility to increase plant material for the propagation study. Barerooted clumps of the sedge were planted in commercially available growing media composed of a mix of compost and volcanic cinder (Menehune Magic Black Cinder Blends, Hawaiian Earth Products, Kapolei, Hawaii). Stock plants were allowed to establish and to set seeds for 6 mo.

Seed Counts and Seed Germination Tests

Prior to field evaluation of hydromulch planting techniques, we conducted seed counts and a seed germination test to estimate the number of seeds per unit weight and the average percent germination of seeds. Inflorescences of *F. cymosa* were harvested and air-dried. Seeds were recovered from crushed seed heads through a combination of sieving and air-blowing until most of the plant residue was removed. Seeds were stored dry (50% relative humidity) at approximately 10 °C (50 °F) until use.

To estimate the number of seeds contained per unit weight, we manually counted 5 samples of seeds, 0.02 g in size. The mean seed count per sample was used for estimating the amount of seeds needed for the hydromulch planting experiment. In addition to seed counts, we conducted a seed germination test to determine the percent germinable seed for a given sample. One hundred seeds were sown in each of 4 Petri plates (100 mm diameter, unsealed) lined with moistened filter paper (Whatman #3, Whatman International, Maidstone, UK). The sown seeds were allowed to germinate inside an incubator (Percival Scientific, Perry, Iowa) with alternating dark and light periods (12 h each, under fluorescent lights) as well as fluctuating day (26 °C/78.8 °F) and night (20 °C/68 °F) temperatures. We evaluated seed germination on a weekly basis. Seeds that had ≥2 mm (0.08 in) radicle or shoot protrusion were counted as germinated. Cumulative percent germination was recorded after 1 mo.

Field Assessment of Hydromulch Planting Techniques

We evaluated 3 hydromulch planting techniques in terms of plant count and percent visual cover from September 2007 to March 2008: 1) hydromulch capped 2-mo-old seedlings (applied by hand to the surface of each experimental unit); 2) hydroplanted 2-mo-old seedlings; and 3) hydroseeding (Figure 1). *Fimbristylis cymosa* seeds and plantlets were prepared 2 mo prior to the application of the hydroplanting treatments. For treatments involving plantlets, seeds were sown in galvanized iron trays filled with a mixture containing 40% (by volume) black volcanic cinder and 60% (by volume) commercial potting mix (Promix, Premier Horticulture, Quakertown, Pennsylvania). Seeding rate was approximately 0.85 g/m^2 or an average of 0.15 g of seed per tray (~2250 seeds). Seeds were allowed to germinate and grow for 2 mo under overhead sprinkler irrigation and full sun conditions. Seedlings were approximately 2.5 cm (1 in) in diameter and had 6 to 7 leaves.

To prepare the planting surface for the hydromulch treatments, 4 raised plots (9.3 m^2 [100 ft^2] in size; 5.08 cm [2 in] in depth) framed with polyvinylchloride (PVC) pipes were installed at the H1-University Avenue off-ramp cloverleaf. The PVC frames were placed on a black plastic woven geotextile fabric to reduce weed pressure. To keep the growing medium in place, the bottom of each plot was lined with a layer of plastic sheeting. Drainage was provided by perforating the plastic sheeting on the low regions of the plot. To ensure a weed-free environment, commercially available compost (Menehune Magic Black Cinder Blends, Hawaiian Earth Products, Kapolei, Hawaii) was used as the growing media for this experiment. After the addition of compost, the plots were limed (Dolomite 65 AG, Chemical Lime Company, Salinas, California) at 2.24 tons per ha (1813 lb/ac) (54.7% $CaCO_3$, 42.6% $MgCO_3$) and fertilized with triple superphosphate (0-46-0) at 224 kg P per ha (200 lb/ac). The growing medium was kept moist prior to planting to maintain soil capillary action.

A day prior to hydromulching, the seedling clumps were separated into individual plantlets through gentle agitation underwater. Seedlings were cleaned and kept moist until ready for use. We used approximately 70 g of plantlets (equivalent to 616 plants) in each of the hydromulch-capped seedling treatments (applied by hand to the surface of each experimental unit) and the hydroplanted seedling treatments. This quantity is equivalent to a sowing rate/planting density of 199 plants/m^2 (18 plants/ft^2). For the hydroseeded treatment, 0.1 g of seeds (containing approximately 1490 seeds) was used to provide a seeding density equivalent to 481 seeds/m^2 (45 plants/ft^2) (Figure 2).

Except for seedlings capped with hydromulch, all materials in each of the 2 other treatments were mixed together and applied using a hydroseeder. Table 1 lists the amount of tackifier (C:tac, Hamilton Manufacturing, Twin Falls, Idaho), paper mulch (NaturesOwn, Hamilton Manufacturing, Twin Falls, Idaho), and water used for each treatment. A hydromulch delivery system (Turbo Turf Modular Hydroseeding System Model No. HS-50-M, Turbo Technologies, Beaver Falls, Pennsylvania) used for applying the treatments consisted of a 190-l (50.2-gal) tank and a 5 × 5 cm (2 × 2 in) centrifugal trash pump calibrated to apply approximately 114 l (30 gal) of hydromulch per min.

During the application of hydromulch, untreated plots were masked with plastic fabric to prevent cross-plot contamination. The hydroseeding machine was completely flushed with water before the next treatment was prepared. Each treatment was

Figure 1. The 3 hydromulch planting techniques evaluated in this study: hydromulch capped seedlings (A); hydroseeding (B); and hydroplanted seedlings (C).

replicated 4 times and arranged in a completely randomized block design. Each treatment covered 3.1 m^2 (33.4 ft^2) of experimental area per block. For the first 4 mo of the experiment, overhead irrigation was applied 3 times per day (early morning, noon, and late afternoon) for 5 min to prevent the hydromulch from drying. After 4 mo, irrigation was reduced and applied once a day (early mornings) for 10 min.

Plant counts and visual percent cover were recorded from 3 randomly selected 30.5 cm × 30.5 cm (1 ft^2) representative portions of each experimental unit. Plant counts were collected for the first 2 mo after planting while visual percent cover was recorded during the first 6 mo after planting. Supplemental hand-weeding was employed during the 6-mo observation period to remove competition and to improve the accuracy of visual cover ratings. Monthly percent visual cover was measured by superimposing 100 square grids on digital photographs of a representative area (Figure 3). Representative areas were photographed at a constant height to provide a cropped sample with square dimensions of 1570 × 1570 pixels. This procedure was facilitated by framing the edges of a PVC square (30.5 cm × 30.5 cm [1 ft × 1 ft]) on the camera viewfinder. Collection of percent visual cover was facilitated by viewing

Plots containing the 3 different hydromulch planting treatments. Photo by Joseph DeFrank

Spreading the seedlings on the plot prior to capping with hydromulch. Photo by Joseph DeFrank

Treatment plots 5 mo after planting.

Treatment plots 6 mo after planting. Photo by Joseph DeFrank

Treatment plots with the 190-l (50-gal) hydromulcher.

Figure 2. Photo displays the amount of *Fimbristylis cymosa* seed used in the hydroseeding treatment. The vial contains 0.1 g or approximately 1500 seeds.

TABLE 1

Amount of planting material, tackifier, paper mulch, and water used for each of the hydroplanting treatments. Hydromulch planting materials were applied using the Turbo Turf Modular Hydroseeding System (Model No. HS-50-M). Each batch of hydromulch covered 3.1 m² of experimental area per block.

Hydroplanting treatments	Planting material	Tackifier	Mulch	Water
Handsown seedlings + hydromulch cap	70 g seedlings (199 plants/m²)	3.3 g	1.36 kg (4400 kg/ha)	51 l
Hydroplanting (plantlets)	70 g seedlings (199 plants/m²)	3.3 g	1.36 kg (4400 kg/ha)	51 l
Hydroseed	0.1 g seeds (481 plants/m²)	1.65 g	0.682 kg (2200 kg/ha)	25 l

Notes: 1 g = 0.035 oz; 1 m² = 10.2 ft²; 1 kg = 2.205 lb; 1 l = 1.06 qt.

the grid-imposed photos in digital imaging software (Adobe Photoshop CS2, Adobe Systems, San Jose, California). Estimations per sample area were assessed by counting the number of squares fully covered with leaves and vegetation. Average percent cover of the 3 sample areas was calculated to obtain the percent cover of a treatment plot.

Repeated measures analysis was carried out using Statistix 9.0 (Analytical Software, Tallahassee, Florida). For plant count data, all 3 treatments (that is, planting methods) were included in the analysis. Tukey's all pairwise comparisons test was used to separate treatment means. For percent cover data, the repeated measures analysis used data only from the hydromulch capped seedlings and the hydroseeded plots. The hydroplanted treatment was excluded in the analysis due to consistently low percent cover values (0–7%) even at 6 mo after planting. Tukey's all pairwise comparisons test was used to separate differences in percent cover between months.

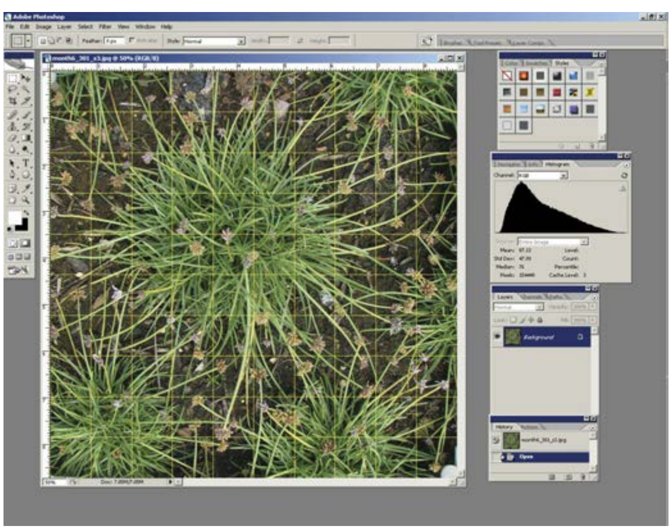


Figure 3. Estimating percent visual cover of *F. cymosa* in Adobe Photoshop. Digital photographs of the sample were superimposed with 100 square grids. Percent visual cover was estimated by counting the number of squares occupied by foliage.

RESULTS

Seed Counts and Seed Germination Test

Average number of seeds per 0.02 g, based on 5 samples, was 298 or approximately 15,000 seeds per g. Average percent germination for *F. cymosa* after 1 mo of incubation was 91 ±2.5%. Seeding density of the hydroseeding treatment therefore contained approximately 437 live/viable seeds per m².

Plant Counts

No significant interaction occurred between treatment and month of observation, therefore treatment means were pooled across months (first 2 mo). Significant differences between planting methods were observed during the first 2 mo after planting. Hydroseeded plots exhibited the highest seedling density based on plant counts (Figure 4). Hydroseeded treatments had an average density of 267 plants/m² with 61% survival of the viable seeds applied to these treatments. Hydromulch capped plots exhibited significantly lower plant density (76 plants/m²) compared to the hydroseeded treatments. Percent survival of hand-sown seedlings based on initial plant density (199 plants/m²) was 38%. Hydroplanted plots exhibited the lowest mean plant counts (2 plants/m²) and percent survival (1%).

Percent Visual Cover

Data analysis did not reveal a significant interaction between the factors of months after planting and method of planting treatments. Means were therefore pooled across planting method treatments within each month. Percent visual cover significantly increased within the first 6 mo of observation (Figure 5). During the first 2 mo after planting, plots (hydroseeded and hydromulch capped seedling treatments) exhibited < 10% cover. At 6 mo after planting, percent cover of plots (hydroseeded and hydromulch capped seedling treatments) increased to 61%. Figure 6 shows the progression of the hydroplanting treatments over the 6-mo observation period.

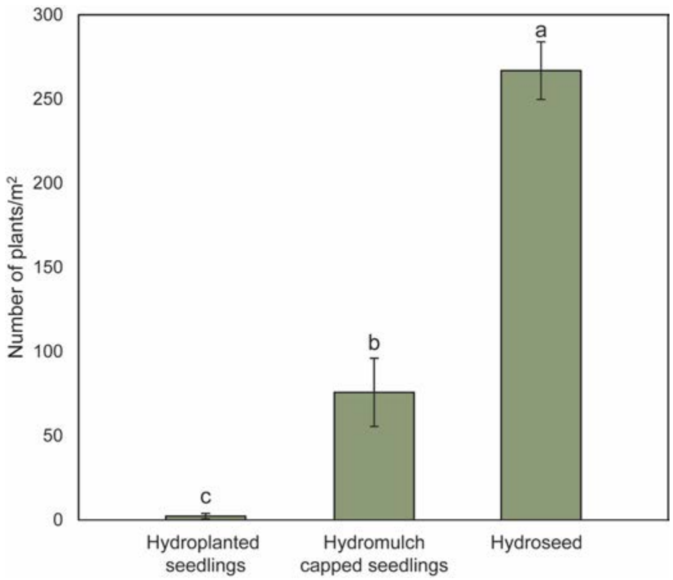


Figure 4. Plant counts per m² of the *F. cymosa* planting treatments pooled over the 2 mo after planting. Hydroseeded treatments exhibited the highest number of plants per m² among the 3 treatments. Values with the same letter are not significantly different at $P < 0.05$, $n = 8$.

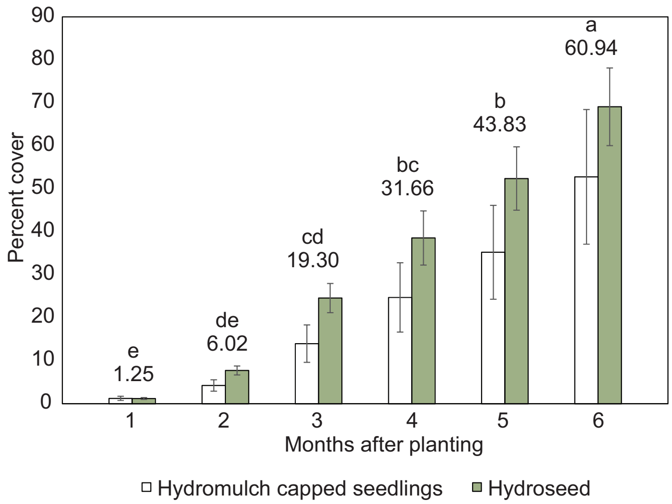


Figure 5. Percent visual cover of *F. cymosa* established for a period of 6 mo. No significant interaction between months after planting and planting treatments were observed. No significant differences between planting treatments were observed. Significant differences between months were observed, therefore, percent visual cover was pooled between hydroseeded and hydromulch capped seedling treatments. Pooled means are shown as numerical values above the bar graphs. Hydroplanted treatment was excluded in the statistical analysis due to zero to low percent cover (<7%). Values followed by the same letters are not significantly different as determined by Tukey's range test at $P < 0.05$, $n = 8$.

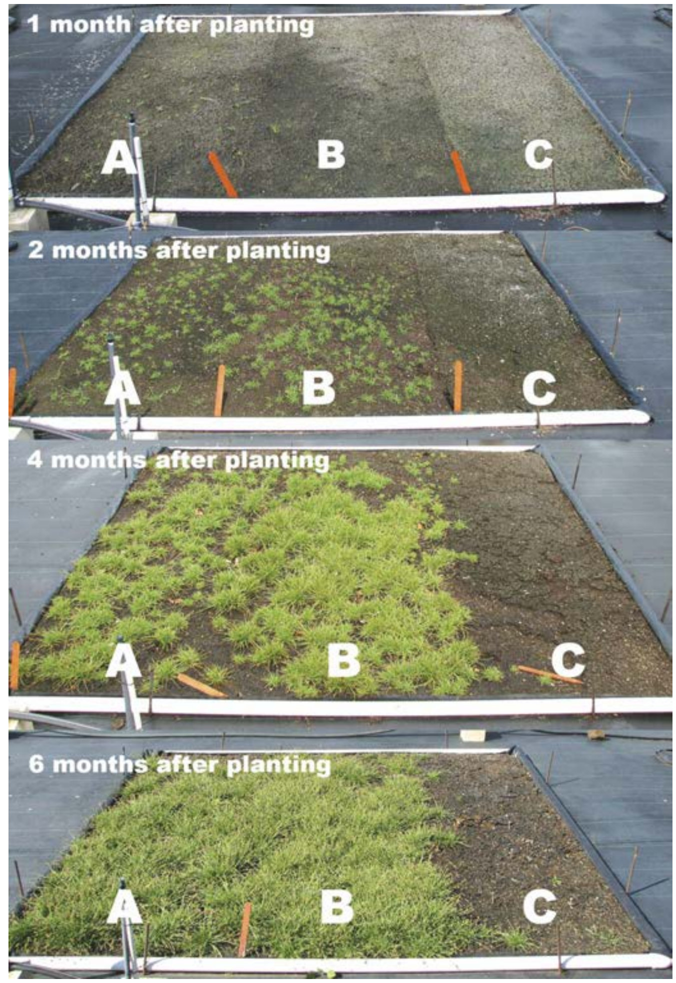


Figure 6. Fimbristylis cymosa hydromulch planting treatments over a period of 6 mo: hydromulch capped seedlings (A); hydroseeding (B); hydroplanted seedlings (C). Photos were taken at 1, 2, 4, and 6 mo after planting.

DISCUSSION

Results indicate that hydroseeding was the most effective and efficient means of establishing large-scale *F. cymosa* plantings. Hydroseeding requires less time and resources to establish the same percent visual cover as hydromulch capping of seedlings. The hydroseeding operation requires only one step, which includes mixing all the materials in one tank and applying it directly to the prepared planting surface. By contrast, the hydromulch capping method requires a 3-step process that includes producing the seedlings (2-mo growing period), then distributing them evenly over the planting area followed by application of the hydromulch cap. Aside from taking less time and resources, hydroseeding also exhibits higher percent cover at all dates after planting as compared to the other treatments. We conclude that hand-sown seedlings provide less coverage because of seedling mortality and slow growth due to outplanting shock.

Figure 7. Mechanical damage incurred by hydroplanted *F. cymosa* seedlings during the planting process.

Failure of the hydroplanted seedlings to produce vegetative cover was attributed to mechanical damage caused by passage through the pump (Figure 7). At the end of the hydroplanting process, pieces of seedlings were often observed in the hydroplanted plots. Although mixing the seedlings in the hydromulch slurry is not recommended, the use of primed or barely germinated seeds may provide better results. A study by Tilley and St John (2013) indicated that either stratified or germinated Nebraska sedge (*Carex nebrascensis* Dewey [Cyperaceae]) seeds can be planted through hydroseeding. Results, one mo after planting, showed that hydroseeded plots had significantly more plants than hydromulch capped plots.

In summary, this study indicates that hydroseeding can be used for large-scale planting and establishment of *F. cymosa*. Hydroseeding takes less time and resources for establishment in contrast to hydromulch capping of seedlings or hydroplanting. The small seed size of *F. cymosa* eased planting operations by reducing the bulk of planting materials and by streamlining the process into a one-step operation. The hydroseeding survival rate is also higher than hydromulch capping of seedlings and hydroplanting of seedlings.

ACKNOWLEDGMENTS

We thank the Hawaii Department of Transportation for providing funding for this study and the USDA NRCS Hoʻolehua Plant Materials Center for providing technical assistance and also for providing stock plants for this study. We thank the Magoon Facility Staff for helping us install the experiments at the H1-University off-ramp research demonstration site.

REFERENCES

Anonymous. 2009. The return of native grasses to Hawaii. URL: http://landscapeonline.com/research/article.php/11696 (accessed Aug 2016). Landscape Online Magazine.

Baldos OC, DeFrank J, Sakamoto G. 2012. Pre- and postemergence herbicide tolerance of tropical fimbry, a native Hawaiian sedge with potential use for roadside revegetation. HortTechnology 22:126–130.

Beard JB. 1973. Turfgrass: science and culture. Englewood Cliffs (NJ): Prentice-Hall. 658 p.

Button EF. 1966. Hydroplanting highway turf. In: Madison JH, editor. Practical turfgrass management. New York (NY): Van Norstrand Reinhold. p 84.

Crago L, Puttock CF, James SA. 2004. Riparian plant restoration: a management tool for habitat restoration in Hawaiʻi. URL: http://hbs.bishopmuseum.org/botany/riparian/ (accessed Mar 2007). Honolulu (HI): Bishop Museum.

Emanual DM. 1976. Hydromulch: a potential use for hardwood bark residue. Princeton (WV): USDA Forest Service, Northeastern Forest Experiment Station. Research Note NE-226. 3 p.

Harper-Lore B. 1996. Using native plants as problem solvers. Environmental Management 20:827–830.

Knapp EE, Rice KJ. 1994. Starting from seed: genetic issues in using native grasses for restoration. Restoration and Management Notes 12:40–45.

Landis TD, Wilkinson KM, Steinfeld DM, Riley SA, Fekaris GN. 2005. Roadside revegetation of forest highways: new applications for native plants. Native Plants Journal 6(3):297–305.

Lukas SB, DeFrank J, Baldos OC, Sakamoto GS. 2015. Response of seashore dropseed and weed species to the preemergence herbicide oxadiazon applied as a component of a hydromulch cap. HortTechnology 25(4):565–568.

Mellon MG. 1989. Hydro-sprigging revolution. Landscape Architect and Specifier News 5:40–43.

[OHA] Office of Hawaiian Affairs. 2015. OHA-5 HB 206/SB435 relating to Hawaiian plants. URL: http://www.oha.org/wp-content/uploads/2015/01/OHA-5-Hawaiian-Plants-External-White-Paper-Final.pdf (accessed 21 Jan 2016). Honolulu (HI): Office of Hawaiian Affairs.

Pill WG, Nesnow DS. 1999. Germination of hydroseeded Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass (*Lolium perenne* L.) in response to seed agitation in the tank. Journal of Turfgrass Management 3:59–67.

Spall G. 1998. Hydroplanting: the way forward for extensive green roofs. Facilities 16:4.

Steinfeld DS, Riley SA, Wilkinson K, Landis T, Riley L. 2007. Roadside revegetation: an integrated approach to establishing native plants. Vancouver (WA): Western Federal Lands Highway Division. p 1–28.

Tamimi LN. 1999. The use of native Hawaiian plants by landscape architects in Hawaii [MLA thesis]. Blacksburg (VA): Virginia Polytechnic Institute and State University. 138 p.

Tilley DJ, St John L. 2013. Hydroseeding improves field establishment of Nebraska sedge regardless of seed treatment. Native Plants Journal 14(2):89–94.

[USDA NRCS] USDA Natural Resources Conservation Service. 2017. The PLANTS database. URL: http://plants.usda.gov (accessed 2 Feb 2017). Greensboro (NC): National Plant Data Team.

Wagner WL, Herbst DR, Somer SH. 1999. Manual of flowering plants of Hawaii. Revised ed. Honolulu (HI): University of Hawaii Press. p 1404–1405.

AUTHOR INFORMATION

Orville C Baldos
Assistant Researcher/Assistant Professor
obaldos@hawaii.edu

Joseph DeFrank
Professor
defrenk@hawaii.edu

Department of Tropical Plant and Soil Sciences
University of Hawaii at Manoa
St. John 102, 3190 Maile Way
Honolulu, HI 96822

Scott B Lukas
Assistant Professor
Department of Horticulture
Oregon State University
Hermiston Agricultural Research and Extension Center
2121 South 1st Street
Hermiston, OR 97838
scott.lukas@oregonstate.edu