

When Smokey Says “No”: Fire-less Methods for Growing Plants Adapted to Cultural Fire Regimes

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Abstract: Two culturally-significant plants (sweetgrass [*Anthoxanthum nitens*] and beargrass [*Xerophyllum tenax*]) are used as case studies for investigating methods of restoring plant populations that are adapted to indigenous burning practices without using fire. Reports from tribal members that the plants of interest were declining in traditional gathering areas provided the impetus for research with both species. In both situations, reintroducing large-scale repetitive burning was not feasible. Field studies of planting with cover crops and manually clearing competing shrubs and herbaceous plants are examined, as well as a greenhouse study evaluating the effect of smoke-water on seed germination. All three experiments yielded significant results when compared to a control. These findings indicate that when reintroducing fire is not feasible, treatments are available that, in some cases, may increase the reproduction and growth of target species.

Keywords: smoke-water, germination, sweetgrass, *Anthoxanthum nitens*, beargrass, *Xerophyllum tenax*

Introduction

Before European settlement of North America, fire regimes were a function of natural events and anthropogenic burning prescribed by Native Americans (Pyne 1982; Boyd 1999). Through the use of burning, indigenous people created and maintained diverse and productive ecosystems that provided resources essential for subsistence (Storm 2004). Fire was used to manipulate the landscape, species distribution, and composition of different habitats (Kimmerer and Lake 2001; Anderson 2002; Wray and Anderson 2003; Storm and Shebitz 2006).

Fire plays an important role in shaping plant communities by influencing patterns of recruitment, thus maintaining native species composition and richness (Pendergrass and others 1999). Without fire, fire-adapted communities change dramatically (Boyd 1999; Peterson and Reich 2001; Copeland and others 2002). Due to the suppression of natural and anthropogenic fire throughout the past two centuries (Boyd 1999; Turner 1999), fires that do occur are much more infrequent, but more intense and greater in extent, than those of pre-settlement North America (Quintana-Ascencio and others 2003). The modification of fire regimes in many prairie, savanna, and open woodland systems has led to an increase in abundance of woody vegetation and declines in native herbaceous understory and prairie species (Wroblewski and Kauffman 2003), and often favors the recruitment of exotics with more tolerant life histories than the natives (Priour-Richard and Lavorel 2000). Pyne (1982) states: “[t]he role of fire in sustaining these landscapes is incontestable; when broadcast burning was suppressed as a result of European settlement, the land spontaneously reverted to forest.”

Plant species and communities that were historically exposed to recurrent fire have become dependent on fire for seedbed preparation, seed germination, early growth of seedlings, and maintenance. Some species and communities are so dependent on fires that, without them, they are becoming rare and endangered (Biswell 1999; Boyd 1999). Fire suppression as an independent factor is the principal threat to 4.1% of the endangered plants in the US; when considered with its effect on additional factors such as invasive species recruitment, its threat dramatically increases (Kaye and others 2001). In fact, The Nature Conservancy has identified altered fire regimes as one of the top five threats facing biodiversity in the US (TNC 2001).

With increased urbanization, budgetary constraints, and local policy restricting prescribed burning, reintroducing fire as a restoration tool is not always feasible. This paper presents alternatives to burning when returning to frequent, low-severity fires is not possible. During the course of 8 years (1999-2007), a series of experiments was conducted in the field and in the greenhouse to examine the most effective means to grow two plant species that are adapted to cultural burning without necessarily reintroducing fire. Two field methods (clearing competition and planting cover crops) and one greenhouse method (smoke-water) are included in this paper. The two species in this research are both basketry plants for indigenous cultures in their respective areas: sweetgrass (*Anthoxanthum nitens*, also known as *Hierochloe odorata*), as used by the Haudenosaunee

(Iroquois Confederacy) of New York, and beargrass (*Xerophyllum tenax*) as used by the Quinault and Skokomish of Washington.

Reports from tribal members that the plants of interest were declining in traditional gathering areas provided the impetus for research with both species (Shebitz 2005). Ethnographic research with both species revealed two possible causes of their decline in traditional gathering sites—unsustainable harvesting practices and the suppression of both natural and prescribed burning over the past century (Shebitz 2005). While the research presented in this paper has been published separately elsewhere (Shebitz 2005; Shebitz and Kimmerer 2005; Shebitz and others 2009a; Shebitz and others 2009b), the use of the various research methods to replace the need to burn is presented together here for the first time.

Species of Interest

Sweetgrass

Sweetgrass (Figure 1) is a perennial grass (Poaceae) native to North America that plays an important role in the lives of indigenous people who reside throughout its range. The plant of interest in this work is one of 23 species throughout the world that have the common name "sweetgrass." The rhizomes of sweetgrass are numerous and slender and are its primary means of reproduction (Small and Catling 1999; Greene 2000). It occurs in a variety of habitats, including moist meadows and swales, along stream banks, at the edges of forests, in forest openings, in wet meadows, low prairies, salt marshes, bogs, lakeshores, and along roadsides and railroad tracks (Walsh 1994; Lynch and Lupfer 1995). Sweetgrass is a mid-successional species,



Figure 1. Sweetgrass growing in a fen in Taborton, NY. (Photo by Daniela Shebitz).

typically found among other grasses, and requires partial to full sunlight. The species is often found in areas that have little competition from taller plants, and in areas that have been disturbed, for example, by fire (Lynch and Lupfer 1995).

Although sweetgrass is most frequently used as a ceremonial smudge and incense (Kavasch and Barr 1999; Shebitz and Kimmerer 2004), it is predominantly used among the Haudenosaunee in basketry (Benedict 1983). While sweetgrass itself was not typically a target for burning, some of the fields from which it was traditionally gathered by Haudenosaunee were burned for hay until the mid 1900s (Shebitz 2005).

Beargrass

Beargrass (Figure 2) is closely related to lilies and is a member of the Melanthiaceae family. It is harvested by tribes ranging from northern California along the Pacific Coast to the Olympic Peninsula and southeastern British Columbia. Tribes such as the Modoc on the Modoc Plateau, the Yurok in northern Coast Ranges, the Maidu in the northern Sierra Nevada, and the Shasta in the Cascades gather young, fresh beargrass leaves to provide the soft background or decorative overlay material in twined baskets (Anderson 2005). A weaver may use up to 2000 beargrass leaves to complete a design in a large basket (Rentz 2003). Preferred leaves grow under semi-shade "...where it became long but not brittle" (Nordquist and Nordquist 1983), and where there is enough sunlight for it to flower (Peter and Shebitz 2006). The anatomical structure of beargrass leaves makes it useful in basket making. Weaving requires materials to be narrow, flexible, and have tensile strength. The reduction in sclerified tissue in the



Figure 2. Beargrass in bloom in a bog on the Quinault Reservation, Olympic Peninsula of Washington. (Photo by Daniela Shebitz).

leaves and resulting pliability after a fire therefore yields improved basketry material (Rentz 2003).

Low-severity burns have long been used by Native Americans to enhance the growth of beargrass and provide basketry material (Hunter 1988; LaLande and Pullen 1999; Rentz 2003; Shebitz 2005). In addition to Olympic Peninsula tribes such as the Skokomish and Quinault, the Yurok Karuk, Hupa, Chilula, Upland Takelma, and others burned beargrass periodically and then harvested leaves from the burned clumps 1 to 3 years later (LaLande and Pullen 1999; Rentz 2003; Anderson 2005). Historically, burns were low-severity, slow-moving surface fires that burned old beargrass growth and up to 95% of living foliage (Hunter 1988; Rentz 2003).

Methods

Field Experiment: Sweetgrass

Cover crops are generally selected for their annual life cycles and characteristics of effective weed suppression and enhanced growth. In this study, hairy vetch (*Vicia villosa*) was selected for use. It is a nitrogen fixer that has been shown to enhance grass growth in legume-grass bicultures and is not persistent once introduced (Ranells and Waggoner 1997; Batte and others 1998; Brandsaeter and others 2000). Because many of the pioneer species that become established following a fire are nitrogen-fixing species (Agee 1993), the nitrogen that vetch contributes can resemble changes in soil chemistry following a fire.

At a Mohawk farm named Kanatsiohareke, in Canajoharie, NY, a field experiment was designed to determine if sweetgrass could be reintroduced successfully and to evaluate the effect of competitors on its growth and reproduction in garden-sized plots. Sweetgrass was grown: 1) in unweeded plots that contained existing old-field vegetation; 2) in manually weeded plots; 3) in combination with hairy vetch to assess the use of a nitrogen-fixing cover crop in alleviating competition following disturbance; and 4) with an annual rye grass (*Lolium multiflorum*), a cover crop that does not fix nitrogen. The experiment was replicated at the LaFayette Experiment Station near Syracuse, NY. This work was published by Shebitz and Kimmerer (2005).

Sweetgrass from nursery stock was transplanted into five replicate plots of each of the four treatments, for a total of 20 plots at both LaFayette and Kanatsiohareke. Transplants were standardized to consist of a maximum of three culms and two rhizomes, with a maximum length of 15 cm (5.9 in). Experimental plots were 2.25 m² (24 ft²) in area, and were separated by 1 m (3.3 ft). Transplants were installed in seven rows of seven in each plot, with 18 cm (7 in) between plants. Transplants were tagged to monitor growth and survival. Plots were tilled in May 2000 prior to planting sweetgrass, with the exception of the treatment with existing old-field vegetation. The seeds of hairy vetch were mixed with water and a pea/vetch inoculant by the name of Nitragin® (EMD Crop BioScience, Brookfield, WI) prior to their dispersal to promote maximum nitrogen fixation ability. The vetch

was sown at a heavy density and was later thinned to 490 plants per plot. Weeding of the sweetgrass monoculture treatment occurred weekly through 15 September 2000. The treatments were not watered throughout the course of the experiment.

Sweetgrass tiller density in each plot was recorded monthly in July, August, and September 2000. At the end of the field season, survival and growth of the sweetgrass were measured, and sweetgrass above-ground dry biomass, number of tillers per plot, survival percentage, and height were calculated. Height was determined from the measurement of five randomly selected sweetgrass blades in each of the 20 plots. The numbered markers that were initially planted with each plug allowed us to determine survival percentage of original sweetgrass transplants. Biomass was sampled from a 0.25 m² (2.7 ft²) quadrat placed in a random location within each plot. Sweetgrass within the quadrat was cut at ground level and dried at 26.7 °C (80 °F) for one week prior to weighing. Sweetgrass height and density was measured in May of the following year to assess growth one year after planting. No additional treatment (weeding or cover crop sowing) was applied during the second growing season.

Field Experiment: Beargrass

The growth and vegetative reproduction of early- and mid-successional species are often limited by competition with neighboring shrubs and herbaceous species. The abundance of beargrass in mid- to late-successional communities is limited due to increased competition and resultant shade (Peter and Shebitz 2006; Shebitz and others 2008).

On the Olympic Peninsula of Washington, beargrass grows from sea level up to the subalpine zone in the USDA Forest Service Olympic National Forest and USDI National Park Service Olympic National Park. The Peninsula's Native American basketmakers rely primarily on the lower elevation beargrass for their basketry since it is generally close to the reservations and easily accessible. Many of the harvesting sites were historically burned, but have now undergone succession, resulting in a more forested habitat with a dense shrub understory.

A field experiment examined the effects of manually-clearing competing shrubs and forbs on beargrass vegetative reproduction compared to low-severity fire and a control. We installed a field experiment to an existing beargrass population within a Douglas-fir (*Pseudotsuga menziesii*) savanna habitat restoration area of the Olympic National Forest, close to the Skokomish Reservation. We installed six replicates of burned and manually-cleared competition treatments as well as a control. Each replicate contained three 8 by 8 m (26 by 26 ft) plots for the two treatments and the control (1.5 m [5 ft] buffer on each side), with 1 to 10 m (3.3 to 33 ft) between replicate plots (Figure 3).

Treatments were applied in September 2004 by the Olympic National Forest fire crew. Fires were low-severity and left most beargrass meristems visible following the burns. In plots that were manually

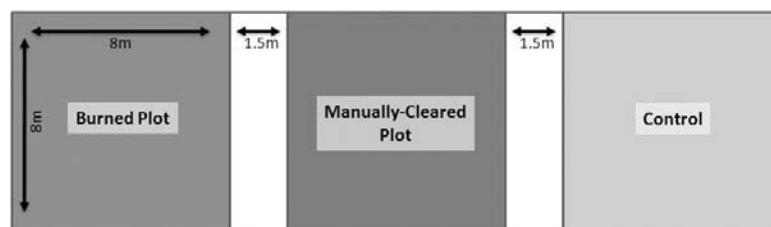


Figure 3. Example of a replicate block established in the Olympic National Forest site with the two treatments and a control. The order of the treatments was random within each block. (1 m = 3.3 ft)

cleared of vegetation, chainsaws, machetes, and weed whackers were used to clear all aboveground vegetation and coarse woody debris from the plots. Beargrass leaves were also cut, but the meristematic region was intentionally left intact to replicate the effects of a burn.

We took measurements in each of 25 contiguous 1 m² (11 ft²) quadrats within each plot prior to treatment. Data collected before treatments and 1 year following the treatments included measurements of beargrass density, cover percentage of all species, and the number of beargrass inflorescences. We randomly selected five beargrass plants in each plot for additional measurements of length of the five longest leaves, height to the highest leaf, widest diameter of foliar crown material (W1), and the diameter perpendicular to this (W2). We marked these five plants in each plot with an aluminum nail hammered into the ground at each of their bases. Each nail was spray-painted one of five colors so that the beargrass could be relocated and remeasured following treatment application.

Greenhouse Experiment: Beargrass Seeds

Smoke is the most striking chemical cue generated by fire. Chemical signals of smoke may not only influence seeds during fires and in the immediate post-fire environment, but can travel far and last for considerable periods after fire. Smoke particles can adhere to plant surfaces, persist in the soil, and be adsorbed to soil particles (Van Staden and others 2000). Egerton-Warburton (1998) demonstrated that the ability of smoke to adhere to soil and plant surfaces plays a role in germination by changing the morphology of some seeds and causing an intense chemical scarification of the seed surface. Fire cues may also deactivate compounds in the soil or the seed coat that inhibit germination (Keeley and Nitzberg 1984). There are two basic methods for exposing seeds to smoke, or the chemicals derived from smoke, that are thought to promote germination. The first is to expose seeds directly to smoke and the other is to indirectly expose seeds to the particulates of smoke through the use of water infused with smoke. The work presented in this paper examines the affect of smoke-water on beargrass seed germination and was originally published in Shebitz and others (2009a).

Without smoke-water, low elevation beargrass requires a 24-hour soak in water followed by a minimum of 8 to 12 weeks of cold, moist stratification (Smart and Minore 1977; Shebitz and others 2009a). A greenhouse study was designed to determine if smoke-water can be used to enhance germination rates of low elevation beargrass and decrease the length of cold stratification.

Mature beargrass seeds were harvested from 20 inflorescences in August 2004 in a bog laurel/Labrador tea/beargrass/sphagnum (*Kalmia microphylla*/*Ledum groenlandicum*/*Xerophyllum tenax*/*Sphagnum* spp.) wetland of the Quinault that is believed to have been historically managed through anthropogenic burning (Shebitz 2005; Shebitz and others 2009b). Seeds were counted, divided into packets of 50, and stored in the Miller Seed Vault at the Center for Urban Horticulture, University of Washington (Seattle, WA) at 15 °C (59 °F) and 20% relative humidity until needed.

Half of the seeds used in this experiment were exposed to smoke-infused water, and the others were exposed to water as the control. The smoke-infused water used in this experiment was created from species associated with the vegetative communities at the Quinault site: salal (*Gaultheria shallon*), sword fern (*Polystichum munitum*), western redcedar (*Thuja plicata*), and beargrass. A charcoal grill was used to make the smoke-infused water. Charcoal was burned on half of the base of the grill and freshly collected vegetation was placed directly above it on the upper grill surface. A pan of water was on the opposite side of the upper grill surface. The grill was covered for 2 hours as the coals burned the vegetation and smoke infused the water in the pan. The water did not reach the boiling point. Once the

smoke-infused water cooled, 200 ml (6.8 oz) were poured into glass containers and 50 beargrass seeds were added to each container. An air pump and stone were then used to circulate the water (with seeds added) for 24 hours. The control treatment involved beargrass seeds added to tap water and electrically circulated for 24 hours.

After the seeds were exposed to the pre-treatment, they were sown in nursery flats measuring 53.3 by 26.7 cm (21 by 10.5 in). These flats were prepared by adding a seeding mix (Terra-Lite Redi-Earth; Scotts-Sierra Horticultural Products Company, Marysville, OH), and were divided into eight quadrats measuring 13.3 by 13.3 cm (5.2 by 5.2 in) using a plastic-lined barrier between the smoke-water and control treatments to discourage leaching between treatment soils. The smoke-infused water and tap water were added to the flats with the beargrass seeds, and the flats were watered and covered with plastic before being placed in cold stratification or the greenhouse.

The seeds underwent cold stratification for one of six time periods: 0, 8, 10, 12, 14, or 16 weeks. The flats testing the effects of smoke-water and water with 0 weeks in cold stratification were placed directly in a greenhouse at 26 °C (79 °F). Those undergoing cold stratification for a designated period of time were stored in a chamber at 5 °C (41 °F) and then moved into the greenhouse. Each treatment was replicated four times with 50 beargrass seeds per replicate. Therefore, a total of 12 treatments were used, with four replicates (200 seeds) each.

Data Analysis

Field Experiments: Sweetgrass and Beargrass

The effects of treatments on the performance of both sweetgrass and beargrass was compared with analysis of variance (ANOVA) using SAS[®] software (SAS Institute Incorporated, Cary, NC). Tukey's method of grouping was utilized to distinguish between significantly different treatments. For sweetgrass, changes in growth and survival were analyzed by treatment for both Kanatsiohareke and LaFayette independently.

Greenhouse Experiment: Beargrass Seeds

The objectives of this study were to determine if seeds being exposed to smoke-water resulted in increased germination rates and/or influenced seed response to increased length of cold stratification. The germination rates of seeds from the two sites were significantly different ($P < 0.001$), so the data for each of the two restoration sites were analyzed separately. A two-way analysis of variance (ANOVA) incorporating the treatment and length of cold stratification was performed using SAS[®] software (SAS Institute Incorporated, Cary, NC). Statistical significance throughout this paper is defined with $\alpha = 0.05$.

Results

Field Experiment: Sweetgrass

Sweetgrass survival was statistically greatest in the hairy vetch plots and the manually-weeded plots at both Kanatsiohareke and LaFayette (Figure 4). After one growing season, the plots in Kanatsiohareke with hairy vetch (HV) as a cover crop, or those plots that were weeded (SG), yielded significantly greater sweetgrass biomass ($P < 0.0001$) and height ($P = 0.0011$) than that of other treatments. The plots sown with annual ryegrass (AR) or left unweeded (VEG), however, had a significantly lower number of sweetgrass tillers and resulting biomass.

Sweetgrass population within a treatment plot increased by as much as four times the original amount during the first growing season and

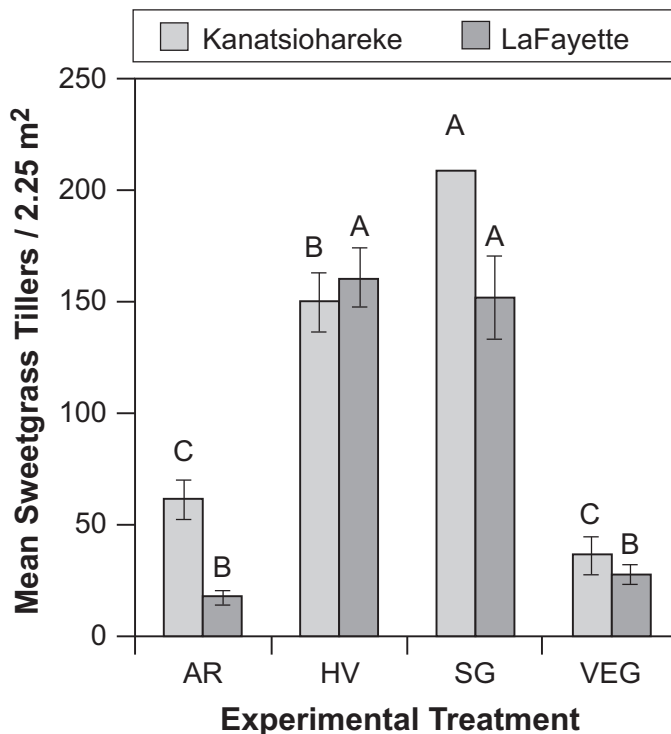


Figure 4. Mean number of sweetgrass tillers per 2.25 m² (24 ft²) plot by treatment in Kanatsiohareke and LaFayette after one growing season; AR = annual ryegrass; HV = hairy vetch; SG = weeded competition; VEG = control with no weeding. Standard error bars are shown. (Figure previously published in Shebitz and Kimmerer 2005).

by as much as 20 times the original amount after one year (Table 1). The significant difference in the height of sweetgrass that was found in plots sown with hairy vetch during the first growing season, however, did not last through the following season. Sweetgrass tiller density continued to increase even after weeding ceased in the plots in which competition was manually controlled. The ability to have increased sweetgrass reproduction and growth, even after weeding ended in SG plots, or after the cover crops were no longer present in HV plots, was an important finding for those individuals interested in growing sweetgrass in garden-sized plots.

Table 1. Sweetgrass growth means for Kanatsiohareke and LaFayette experiment sites after one year (Tukey's method of grouping at $\alpha=0.05$); SG= weeded competition plots; VEG=vegetated plots; HV=hairy vetch plots; AR=annual rye plots.

Site	Treatment	Tillers/ 2.25 m ² *	Average height (cm)**
Kanatsiohareke	SG	481.6 ^a	26.2 ^a
	VEG	27.8 ^c	36.2 ^a
	HV	353.2 ^{ab}	39.0 ^a
	AR	150.6 ^{bc}	28.2 ^a
LaFayette"	SG	642.2 ^b	38.4 ^a
	VEG	26.8 ^c	33.6 ^a
	HV	993.0 ^a	40.4 ^a
	AR	14.0 ^c	19.2 ^b

Means with the same letter within the same column are not significantly different. Value is significant at $\alpha=0.05$.

*2.25 m² = 24 ft²

** 1 cm = 0.4 in

Field Experiment: Beargrass

One year after treatments of clearing competition manually and through burning were applied, the number of beargrass shoots was significantly higher in manually cleared plots than in the control. The mean number of beargrass shoots increased by 18 cm (7 in) the burn plots and 23 cm (9 in) the control, as compared to a mean increase of 99 cm (39 in) the manually cleared plots ($P=0.01$). The cover percentage of beargrass, however, was significantly lower in cleared ($P=0.02$) and burn plots ($P=0.01$) when compared to control plots. Shrub cover was significantly reduced in both burn ($P<0.001$) and cleared plots ($P=0.01$) compared to control plots, whereas the cover percentage of all forbs was significantly higher in burn plots than in reference plots ($P=0.08$) (Table 2).

All 90 beargrass individuals measured in 2004 (five in each of the 18 plots) were alive during the 2005 field season, regardless of treatment (Table 2). Beargrass exposed to low-severity burns had a significantly lower leaf length ($P=0.03$), shorter height ($P=0.02$), and smaller crown area ($P=0.04$) than individuals in control plots. Measurements of beargrass in the plots where vegetation was manually cleared, however, were not significantly different than those in control plots. The flowering rate was significantly lower in cleared plots than

Table 2. Comparison of changes from pre-treatment data to 1-year post-treatment data following installation of the 2004 field experiment on beargrass growth on the Olympic National Forest.

Variable	Burn		Clear		Control		P-value
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	
Leaf Length (cm)*	-11.53	4.97	-9.59	4.87	-3.93	6.16	0.050
Height (cm)*	-7.90	4.21	-4.87	2.70	-0.37	6.37	0.030
# Inflorescence	0.67	1.21	3.50	1.38	4.17	2.99	0.020
# Shoots	7.17	6.67	39.17	26.65	9.17	15.13	0.010
% Cover	-5.59	3.25	-5.54	3.25	-1.28	1.67	0.010
% Forb Cover	-2.69	2.73	-7.84	3.20	-7.65	5.25	0.060
% Graminoid Cover	-1.11	1.87	-0.71	4.09	-3.93	6.82	0.450
% Shrub Cover	-34.38	16.08	-25.78	6.55	-5.38	7.74	0.001

P-value compares the changes in the variables between burn, cleared, and reference plots. Significant P-values are in **bold** ($\alpha=0.05$).

*1 cm = 0.4 in

in control plots ($P=0.05$), but the number of beargrass flowers was not significantly different between burn and reference plots ($P=0.80$)

Greenhouse Experiment: Beargrass Seeds

The earliest germination occurred after 10 weeks in cold stratification. The greatest germination rates for the Quinault seeds (41%) occurred after being soaked in smoke-water and then undergoing 14 weeks of cold stratification. The smoke-water treatment generally resulted in greater seed germination regardless of length of cold stratification ($P=0.017$) (Figure 5).

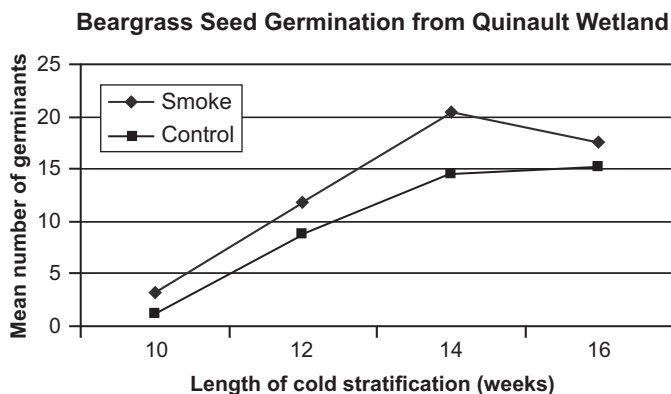


Figure 5. The mean number of beargrass seeds that germinated after exposure to smoke or the control for 10, 12, 14, or 16 weeks in cold stratification.

Discussion

Many plant resources were historically managed through indigenous management techniques such as burning, pruning, or harvesting. With changes in management over time, the plants themselves may decline in both abundance and quality. Simultaneously, as the resources diminish, the traditions that rely on them may become threatened (Shebitz 2005). The studies presented took place on opposite coasts of North America and differed in regards to the Native American cultures, the plant species, and sites involved. The continuation of traditions such as basketry is dependent upon the availability of culturally significant resources. The restoration projects presented were designed to not only restore basketry plants to their native habitat, but also to enable cultural traditions associated with those plants to continue (Shebitz 2005).

The high rates of sweetgrass growth and survival in the plots with vetch found in this research may be the result of both the weed suppression and the nitrogen-fixing capability of the legumes. In addition, the partial shade established by the presence of the hairy vetch might have contributed to the increased sweetgrass height. The increased height and abundance of sweetgrass in the plots with hairy vetch contributes to its value as basketry material. The effects of hairy vetch on sweetgrass height and the minimal effort that is required to maintain plots with the cover crop suggest that basketmakers can benefit from planting sweetgrass with hairy vetch. It is essential to note, however, that hairy vetch is not native to North America and, while used in this study, is not suggested for use in restoration projects that aim to enhance the population of native plant communities.

For beargrass, it was found that manually clearing areas of vegetation and coarse woody debris may result in an increase in beargrass shoot number after only 1 year (Shebitz and others 2009b), and that exposing seeds to smoke-water before undergoing cold stratification may increase germination rates (Shebitz and others 2009a). It is essential to note, however, that for each research study presented in this

paper, attempts were made to replicate the experiments at different sites and from different sources of beargrass seeds. Not all were effective at generating a significant response. The success of such methods, therefore, is not always guaranteed and it may require multiple trials to yield desired responses.

When reintroducing fire to a restoration project is not feasible, it is still possible to encourage the growth of those plant species that are fire-adapted. One must understand, however, that just as habitats that had experienced repetitive cultural burning would have been exposed to a recurrent disturbance, fire-adapted plants, and the areas to which they are reintroduced, would have to be frequently maintained. This commitment of time and energy is often not a problem if the species of concern is still used by tribal members. In fact, the community involvement in activities such as weeding and collecting seeds can play a vital role in not only maintaining healthy populations of the plants, but also in reinforcing ecological knowledge and traditions associated with those species.

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