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Fiddling Around with Fiddleneck: Seed Collection, Processing, and Propagation of *Amsinckia tessellata*. Preliminary Report, 2023

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ABSTRACT

Native forb plant material options for restoration and reclamation projects in semiarid environments are limited in the Intermountain West, USA. To facilitate adoption and use of novel species by seed producers and end users, an understanding of basic plant behavior like germination and establishment and production potential is required. Bristly fiddleneck (*Amsinckia tessellata* A. Gray [Boraginaceae]) is an early seral native forb that may have potential as a conservation species due to its ability to establish in highly disturbed environments and compete against invasive annual grasses. We conducted a series of laboratory and field experiments with bristly fiddleneck to examine germination requirements, wildland seed collection methods, and seed cleaning techniques . Highest germination (93%) was achieved with diurnal conditions and 18/10 °C temperatures in an aerated bath environment. Seed germinated readily when planted on the soil surface on loam, fine sandy loam and clay loam soils but showed poor emergence when planted at 1 and 2 cm depths. Harvesting from wildland stands using a racquet and hopper was faster and produced greater seed yields than clipping stems. Seed cleaning methods are also detailed. Comparisons of agricultural harvesting techniques are planned for the 2024 growing season.

Key Words
forb, germination, seeding depth, seedling vigor

Nomenclature
USDA NRCS (2023)

INTRODUCTION

Native forb plant materials are needed to meet restoration and conservation demands in the Intermountain West of North America (Shaw et al., 2005). Large scale invasion of introduced exotic grasses such as cheatgrass (*Bromus tectorum*) has altered local fire recurrence intervals and increased the size and scope of wildfires in the region (Pilliod et al., 2017). Fire regime changes from cheatgrass invasion have decreased native species plant diversity (Humphrey and Schupp, 2001; Mahood and Balch, 2019) and diminished site resilience (Chambers et al., 2007). Cheatgrass has several traits that allow it to invade and persist, including low temperature germination and quick establishment and reproduction (Barak et al., 2015). Concurrent germination of competitive native species has been suggested as a desirable trait in native plant materials, as plants that are ecologically and phenologically similar to invasives can provide direct competition at key growth stages (Forbis, 2010; Barak et al., 2015; Csákvári et al., 2023). To date it has been difficult to locate suitable species that germinate at low temperatures to compete against cheatgrass (Barak et al., 2015).

Spatiotemporal functional group diversity has been shown to improve site resilience (Tilman and Downing, 1994; Pokorny et al., 2015). One particularly underrepresented group of plant materials with potential to meet these needs is the early seral species (Tilley et al., 2022a). Because they have evolved to be adapted to disturbed conditions, early seral natives can compete better against invasive annuals than species adapted to later seral stages. Early seral natives often show better establishment in areas invaded by exotic annual grasses than late seral species (Uselman et al., 2015), and they have been shown to reduce biomass and seed production of invasives (Leger et al., 2014; Perry et al., 2009). Early seral forbs have also been shown to benefit native pollinators. For example, use of early seral forbs in restoration seed mixes in Wyoming gas fields increased insect abundance and

Figure 1. Scorpioid cyme inflorescence of bristly fiddleneck. Photo by Mary Wolf.

biodiversity compared to non-restored reference sites (Ballard et al., 2013; Curran et al., 2022).

Bristly fiddleneck is a native annual forb which appears to meet several of the desired criteria for early seral plant materials. Bristly fiddleneck is widespread, occurring in all western states from New Mexico north to Idaho and into British Columbia (USDA NRCS, 2023). Plants are 30 to 60 cm (12 to 24 in) tall with flowers arranged in a scorpioid cyme common to the Boraginaceae (Figure 1). This species is characterized by small flowers, homostyly, and rough, bumpy (tessellate) nutlets (Figure 2) (Ray and Chisaki 1957; Welsh et al., 2003). Bristly fiddleneck is largely self-pollinated, but cross pollination and even hybridization with other *Amsinckia* have been observed (Ray and Chisaki, 1957). Visitation to the flowers by the native bees *Anthophora neglecta*, *Melecta edwardsii*, and *Osmia* spp., is documented (DiscoverLife, 2023). Bristly fiddleneck has numerous useful restoration qualities. Fiddleneck has been shown to significantly reduce the biomass of red brome (*Bromus rubens*) in a controlled greenhouse study (Abella et al., 2011), while Leger et al. (2014) showed bristly fiddleneck reduced cheatgrass biomass by 97% and reduced seed production significantly in greenhouse trials.

Information on basic establishment and seed production methods and attributes is needed to facilitate adoption of bristly fiddleneck in the seed industry (Winters, 2023). Likewise, basic germination and adaptation information is needed to guide restorationists with seeding efforts. For example, information is needed on soil adaptation and planting depth to provide recommendations for conservation practices (Rawlins et al., 2009; Bushman et al., 2015; Tilley et al., 2022b; Ogle et al, 2023). Germination speed, referred from this point forward as coefficient of germination (CG), can also be a critical trait for successful establishment in arid and semiarid environments (Agneray et al., 2022; Christie et al., 2022). Limited germination information for bristly fiddleneck is presently available. Forbis (2010) showed bristly fiddleneck germinates better in light than dark, and cold moist stratification resulted in slight increases in germination but not significantly so. Leger et al. (2014) also indicated bristly fiddleneck is capable of germinating during cold periods and does not require stratification, but cold temperature limits for the species were not defined.

Figure 2. Bristly fiddleneck seeds (nutlets). Scale is 1 mm. Photo by Derek Tilley.

Seed production requirements can be a limiting factor in acceptance and seed availability (McCormick et al., 2021). If highly specialized equipment and methods are required, the cost of seed produced can become prohibitive to end users or unprofitable to producers. Wildland harvesting is currently the only means of obtaining bristly fiddleneck seed, though small-scale production has been initiated for government agencies (de Queiroz et al., 2021). De Queiroz et al. (2021) suggested swathing and windrowing of bristly fiddleneck as possibly more

efficient than hand harvesting. They also indicated a 100% increase in seed yield when growing bristly fiddleneck plants on weed barrier fabric compared to plants grown without fabric, though it was not indicated if this increase was due to better production or because it was possible to sweep shattered seed off the fabric.

There are several obstacles to overcome before fiddleneck seed can be produced commercially. For example, indeterminate seed maturation, coupled with seed that readily shatters, complicates seed harvest. Single-harvest methods (direct combining) are unlikely to achieve maximum yields because much of the seed is lost either to shatter or because of indiscriminate collection of immature seed along with the ripe seed. Also, fiddleneck leaves and stems are covered with stiff hairs and bristles (Figure 3) making hand harvest and mechanized seed processing difficult and potentially hazardous.

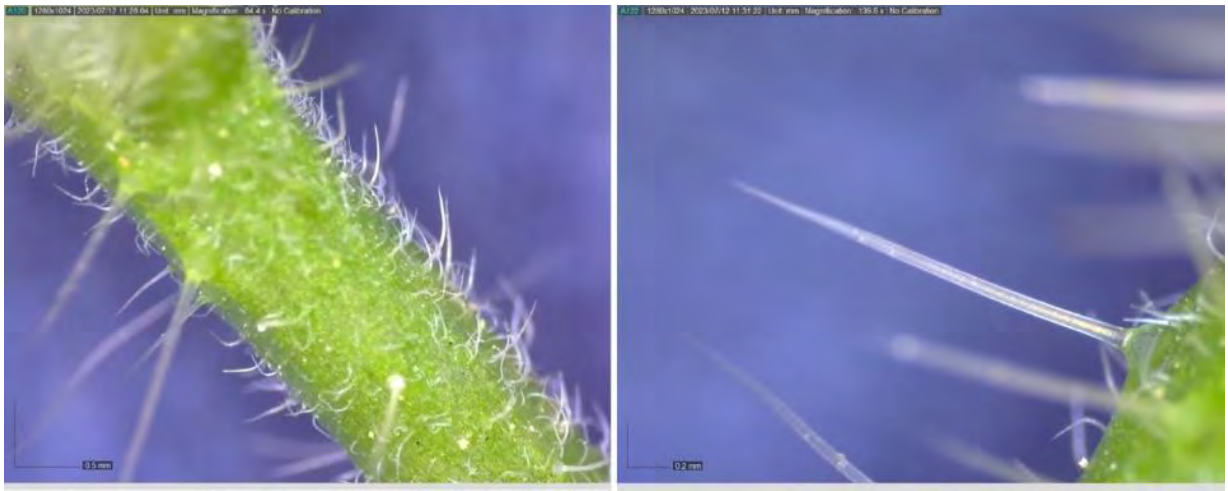

Figure 3. Bristly fiddleneck vegetation is covered with sharp, bristly hairs that can cause irritation to skin and eyes. Scale is 0.5 mm (L) and 0.2 mm (R). Photos by Derek Tilley.

To address obstacles to the successful seed production of fiddleneck, various experiments were conducted including non-replicated seed collection and seed processing methods. Additionally, results of replicated germination trials and greenhouse experiments to evaluate bristly fiddleneck seedling emergence from various seeding depths and soil compositions are presented.

MATERIALS AND METHODS

Wildland seed harvest

To minimize injury from fiddleneck bristles, we wore protective gear including a face mask, goggles, gloves, full body coveralls, and irrigation boots (Figure 4). A common seed collection method is to clip stems just below the inflorescence. To maximize seed yield, we targeted stems on which the bottommost seeds (most mature) were shattering or had already shattered. Stems were stored in paper sacks or laid out on a shop floor on butcher paper and allowed to dry from two to several weeks in a well-ventilated room. An alternate harvest method uses a racquet to beat seed heads and a hopper to collect the dislodged seed (Tilley et al., 2022b; Jensen, 2004). Raquet and hopper methods allow for multiple harvests and require less hands-on

Figure 4. Wildland seed harvesting of bristly fiddleneck requires protective clothing and eyewear. Photo by Mary Wolf.

removal of stems. Racquet harvesting also does not create as much inert biomass from stems and leaves as the clipping method (Figure 5).

Figure 5. Raw collected material of bristly fiddleneck harvested by racquet and hopper (left) and clipping (right). Material collected using a racquet and hopper can be directly fed into cleaning equipment, while clipped stems require crushing and rough screening. Photos by Derek Tilley.

To compare the efficiency and efficacy of these methods, we collected seed from two wildland stands, Rinker Rock Creek Ranch located in the Wood River Valley, Blaine County, Idaho and Curlew National Grassland, Oneida County, Idaho. Both stands were roughly 3x10 m (10x30 ft) of densely populated plants. At the Rock Creek site we completed a single harvest using the clipping method. Time expended harvesting was approximately 60 minutes. At the Curlew National Grassland site, we made two harvests (1 week apart) using the racquet and hopper method. Each harvest took approximately 10 minutes.

Seed cleaning

Bristly fiddleneck seed cleaning requires brushing, milling or other methods to dislodge seed from the flowers, which results in airborne irritating bristles. To reduce the risk of irritation to skin, eyes, and lungs, we wore protective gear as described above during rough cleaning (Figure 6). Paper bags containing the stem clipping inflorescences were placed in a large, galvanized tub or in a large cardboard box and repeatedly stepped on to break stems and dislodge seed. To minimize bristles released into the air, this was done slowly and gently. Crushed material was then hand screened to remove larger stem and leaf pieces using a 6.3 or 13 mm (0.25 or 0.5 in) screen. Material collected using a racquet and hopper did not contain stem material and did not need to be crushed or pre-screened.

Material from both harvesting methods was threshed using a Westrup laboratory brush machine (Slagelse, Denmark) with the gate closed to allow seed to fall through the drum to the tub below. An airlift vacuum system was applied to suck bristles and dust away from the user. After threshing, seed

was separated from inert material using a Westrup 3-screen cleaner (Slagelse, Denmark) with a 2.1 mm (0.08 in) upper screen to remove larger inert material and a 6x24 bottom screen for smaller matter. An airflow column was also used to remove dust and unfilled, light seed. We repeated the air screen process 3 times to maximize purity. Following processing, we weighed 4 replications of 1,000 seeds from 2 sources, Baker City, OR and Curlew National Grassland, ID to calculate average seeds per pound.

Figure 6. Processing of small collections of bristly fiddleneck seed collected by clipping. Clipped stems are crushed while still in the bag followed by rough screening to remove stems. The remaining material is then processed using a brush machine and air-screen separator. Photos by Derek Tilley.

Germination

Seed harvesting by clipping stems allows for post-harvest ripening and increases seed yields for some species (Tilley et al., 2022b). However, we observed a significant number of green nutlet clusters from clipped fiddleneck material. To test whether the green nutlets had achieved full maturation and were viable, we conducted a non-replicated germination test. Thirty (30) clusters of 4 green seeds were placed in mesh bags in an aerated water bath next to 40 dark, ripe seeds in an adjacent bag per Tilley and Picket (2021), see below for full details. Significant differences were obvious in only 4 days; seven out of 120 (6%) of the green seeds germinated compared to 19 of 40 (48%) ripe seeds. These findings agree with de Queiroz et al. (2021) who indicated bristly fiddleneck should be cut for harvest when the inflorescence is dry. Based on these results we proceeded to use only fully ripe seed for the following experiments.

To better understand bristly fiddleneck germination and its potential as an early successional forb for restoration, trials were conducted to determine if germination occurs at temperatures comparable to cheatgrass germination temperatures. Additionally, aerated water bath (bubbler) trials were conducted to determine if seed germination could be improved and synchronized (Tilley, 2013; Tilley and Pickett, 2021). In total we examined 9 germination treatments with seeds placed on blotter paper, plus 2 treatments in bubblers (Table 1). All treatments received 4 replications of 50 seeds. Three temperature regimes were tested: a constant warm condition 22 °C (72 °F), cooler with fluctuating day/night temperatures 18/10 °C (64/50 °F), and a very cold 2 °C (36 °F) constant

temperature. Increased germination observed in bubblers may have resulted from decreased fungal pressure. To test if fungus was a significant factor, we included a bleach treatment to seed germinated on blotter paper in the 18/10 °C, 22 °C and 2 °C environments. Seed was soaked for 10 minutes in a 1:8 solution of bleach and distilled water followed by a 2-minute rinse under tap water (Luna et al., 2009). Finally, we included a 30-day cold/moist stratification (2 °C) treatment followed by germination in the 18/10 °C blotter environment.

Table 1. Bristly fiddleneck germination treatments, temperatures, growing media, and pretreatments.

Treatment Name	Temperature (°C)	Growing Medium	Stratification
Blotter2C	2	Blotter paper	No
Blotter2C+Blch	2	Blotter paper	No
Blotter18/10C	18/10	Blotter paper	No
Blotter18/10C+Blch	18/10	Blotter paper	No
Bubbler18/10C	18/10	Aerated water	No
Strat+Blot18/10C	18/10	Blotter paper	Yes
Blotter22C	22	Blotter paper	No
Blotter22C+Blch	22	Blotter paper	No
Bubbler22C	22	Aerated water	No

Seed for the germination trial was collected from a stand at Baker City, OR in 2022. For the Blotter treatments, we used standard 95x70x45 mm germination boxes with dimpled blue blotter paper rested on Versa-Pak germination paper soaked with distilled water (Figure 7). For the bubbler treatments, we followed Tilley and Picket (2021) by submerging seeds in a fine mesh bag into a 0.95 L Mason jar filled with 500 mL distilled water. Aeration was added with a Profile 1500 aquarium air pump fitted with a 2.5 cm bubbling air stone (Figure 7) with all 4 replications placed in the same jar but kept separated in fine mesh bags. All treatments were subjected to a 15 hr light, 9 hr dark cycle. Germination was evaluated weekly in order to calculate CG, and final germination percentage (FG) reported. The germination trial was conducted in a Percival germination chamber (Percival Scientific, Inc., Perry, IA) except for the 22 °C treatments, which were conducted at room temperature under a 15-hour light/9-hour dark cycle provided by LED grow lights from an AeroGarden Bounty Basic home hydroponics unit (AeroGrow International, Inc., Boulder, CO). Seedlings were counted as "germinated" if the cotyledon, seed coat, or hypocotyl were visible. Seedlings were removed after each counting.

Figure 7. Germination experiments were conducted in germination boxes with seed placed on blotter paper and in aerated water baths (bubblers). Photo by Derek Tilley.

CG was calculated using the method described by Maguire (1962) where the number of new germinants at each counting (in this case, 7, 14, 21 and 28 Days After Initiation (DAI)) are divided by the DAI and the values are summed at the end of the test (equation below). A comparatively higher CG indicates a faster germination rate.

$$CG = \left(\frac{no.of\ seedlings}{DAI\ first\ count}\right) + \left(\frac{no.of\ seedlings}{DAI\ second\ count}\right) + \cdots + \left(\frac{no.of\ seedlings}{DAI\ final\ count}\right)$$

Emergence

Seedling emergence from three seeding depths was evaluated in soils of three texture classes, a Declo fine sandy loam (FSL), Declo loam (L) and a Fingal clay loam (CL), collected from sites in Southern Idaho. The soil was gently broken up and screened through 2.1 mm (0.08 in) screens to remove larger clods, weed seeds and other inert material. We filled 10x10 cm (4-in) pots with soil to a depth of 5 cm (2 in), added 50 seeds, then buried the seed to the appropriate depth of 0, 1, or 2 cm (0, 0.4 or 0.8 in) (Figure 8). The pots were placed in the greenhouse in a randomized complete block design with 4 replications where temperatures ranged from 15 to 30 °C (60 to 85 °F). Pots were irrigated via overhead sprinklers for 20 minutes daily. . We counted seedling emergence weekly for 6 weeks (anticipating longer emergence time from deeper placement). Seedlings were counted as "emerged" if the cotyledons were visible. Seedlings were removed at each counting.

Figure 8. We tested seedling emergence of bristly fiddleneck seed planted at 3 depths (0, 1 and 2 cm) in 3 soil textures: a Declo fine sandy loam (FSL), Declo loam (L) and a Fingal clay loam (CL). Photo by Derek Tilley.

Agricultural Harvesting

In the second year of this project (2024), commonly used seed harvesting techniques will be evaluated on a bristly fiddleneck seed production field of bristly fiddleneck. Wildland collected seed from southeastern Idaho will be established in a field at IDPMC in the spring of 2024. The production field will be a single 146 m (480 ft) long linear strip of 2 m wide, 116 g (4.1 oz) polypropylene weed-barrier landscape fabric. Weed fabric is used to reduce the abundance of weeds that can interfere with production and reduce seed quality. It can also be effective at reducing soil moisture losses due to evaporation and result in better growth and production (Simonson et al., 2006). The experiment will be a randomized complete block design with 4 replications. The fabric strip is to be divided into 7.3 m (24 ft) long plots, each containing approximately 26 plants.

Three or four harvesting methods will be evaluated, 1) racquet-and-hopper, 2) rotary brush harvester (Flail-Vac), 3) swathing/or direct combining, and 4) possible combining following an application of Pod Ceal ®. Combining is a preferred seed harvesting method as it requires only a single mechanical harvest. Racquet-and-hopper harvesting by hand is commonly used for wildland seed collecting and is especially useful for gathering seed of indeterminate species. While it is effective at small-scale harvesting, it requires high labor inputs (Davison, 2003; Jensen, 2004; Tilley et al., 2022b). Flail-Vac harvesters (Woodward Flail-Vac Seed Stripper, Ag-Renewal Inc, Weatherford, OK) are commonly used in native forb and grass seed production (Simonson and Tilley, 2016; Tilley et al., 2018). Flail Vacs can be useful tools for harvesting forb seed but can be highly destructive and can

limit the number of harvests of indeterminate flowering species. Flail Vac harvests rely on nylon brushes in the header whipping plants at high speeds to remove the seed which can result in significant damage to mature and unripe flowers (Simonson and Tilley, 2016). We will not evaluate swathing and combining because we found no evidence of post-harvest ripening during the 2023 germination tests.

Combining will be done with a Wintersteiger (Ried im Innkreis, Austria) plot combine. To obtain the optimum yield for a single pass harvest, harvest will occur when the flowers and fruit in the middle of the inflorescence appear ripe (lower seed has begun to shatter, but upper flowers are still blooming). . The racquet-and-hopper harvest will be done with a badminton racquet and a home-made 1 m (3.3 ft) diameter hoop with nylon catch hopper. Flower heads will be beaten periodically to capture as much seed as possible. To maximize seed yields, three or four racquet-and-hopper harvests are anticipated. Flail-Vac harvests can potentially occur multiple times in a season depending on the level of damage caused during the first harvest. The Flail Vac is run with a brush speed of 400 RPM and tractor speed of 1.9 km/h (1.2 mph).

Seed samples from each harvesting method will be sent to a seed laboratory for TZ and purity analysis to determine if each method may favor collecting of seeds of certain size, weight, or age.

Experimental Analysis

Data for all experiments were tested for normality using a Shapiro-Wilk test to determine the appropriate test to analyze variance. Data from the germination experiment were not normally distributed, therefore FG and CG data were transformed using square root transformation function in Statistix 10 Analytical Software (Tallahassee, FL). Transformed data were analyzed using a one-way analysis of variance (ANOVA). Means with difference at 5% level of probability were separated using Tukey's Honest Significant Difference at $P< 0.05$. The seedling emergence experiment was analyzed using the factorial AOV procedure in Statistix 10 with depth and soil texture as factors. Planting depth and soil texture emergence data were unsuccessfully transformed for ANOVA; thus, a Kruskal-Wallis one-way ANOVA was used for data analysis. Data from wildland harvesting and seed cleaning tests were not analyzed statistically.

RESULTS AND DISCUSSION

Wildland harvest

Stem cutting harvesting from the roughly 3x10 m (10x30 ft) stand at Rock Creek for 60 minutes yielded 8 grocery sacks full of material. Harvest and cleaning activities resulted in a fair amount of skin and eye irritation from airborne bristles. After cleaning, the harvested material yielded 160 g (0.35 lb) of clean seed. Stem cutting is obviously inefficient on a *potential seeds per plant* basis. In comparison, two racquet and hopper harvests, one week apart at 10 minutes each (20 minutes total) yielded a total of 240 g (0.52 lb) of clean seed. Raquet and hopper harvests were easier to clean because very little stem material was present. However, because it is more indiscriminate than stem clipping, it resulted in more collected weed seed.

These harvest comparisons were done from distinct but visually similar stands. Both sites had very dense, solid stands of robust fiddleneck, 0.3 to 0.6 m (1 to 2 ft) tall, with some interspersed weeds. Yields are reported as suggestions of what could be expected from wildland harvest but stand size, plant productivity, and plant density will vary from site to site.

Seed cleaning

The cleaning techniques used resulted in seed lots with an average purity of approximately 95% with the remainder being mostly inert material (stems and chaff). Seed from the Baker City, OR population averaged 542,000 seeds/kg (246,000 seeds/lb), and seed from Curlew National Grassland, ID averaged 596,000 seeds/kg (271,000 seeds/lb). The overall average for both populations was 570,000 seeds/kg (259,000 seeds/lb).

Germination

We saw significant differences in FG between germination treatments ($P < 0.0001$) (Figure 9). The highest observed FG (93%) was achieved by the Bubbler 18/10 treatment. Significantly greater FG was observed in the bubbler treatments compared to the blotter treatments at 18/10 °C and 22 °C. The Bubbler18C treatment resulted in a 55% increase in FG over Blotter18C+Blch, and FG in the Bubbler22C treatment was 170% greater than seed in the Blotter22C treatment.

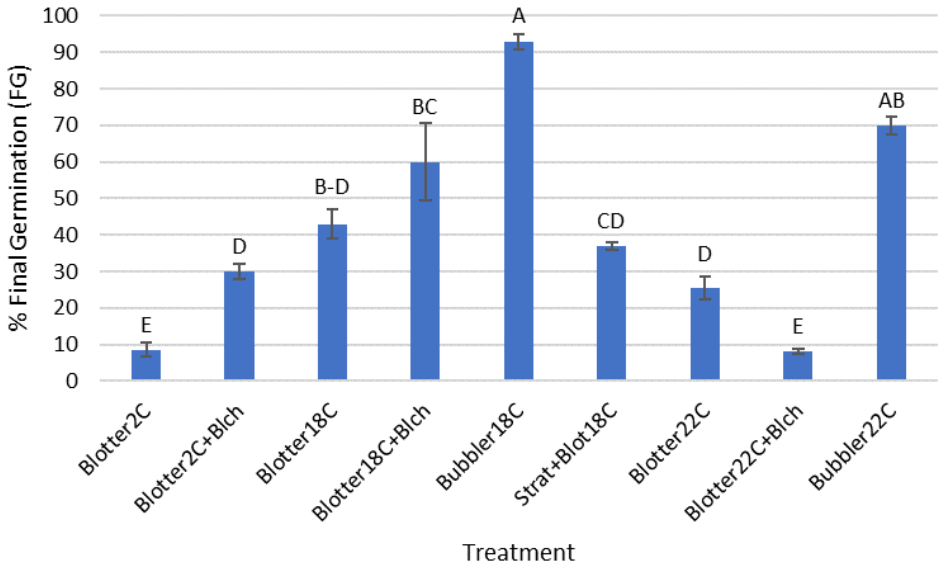

Figure 9. Percent final germination (FG) of bristly fiddleneck seedlings after 4 weeks in 2 growing media (blotter and bubbler) and 3 temperatures (2, 18/10, and 22 °C). Error bars are ±1 standard error. Different letters indicate significant differences in mean percent emergence at p < 0.05.

Temperature had a significant effect on germination of bristly fiddleneck. FG from the Bubbler18/10C treatment was 33% greater than seed germinated at 22 °C in the same environment, though the difference was not statistically significant. However, in the blotter environment, seed germinated at 18/10 °C was significantly greater than at 22 °C (60% and 26%, respectively) We also observed low FG of seed at 2 °C (30% with a bleach pre-treatment and 8.5% without bleach).

The addition of a bleach pre-treatment had mixed results. Bleach significantly improved germination of seed at 2 °C by nearly 3-fold. Germination was higher in the Blotter18/10C+Blch treatment compared to no bleach treatment, though not significantly so. The bleach treatment followed by 22 °C germination environment resulted in significantly lower germination than non-bleached seed.

Previous reports indicated that stratification was needed to germinate recently harvested bristly fiddleneck seed (Ray and Chisaki, 1957). Seed used in these trials had been in storage for 1 year and may have satisfied that requirement. In this experiment, FG of stratified seed germinated at 18 °C (37%) did not differ significantly compared to non-stratified seed (43%).

Higher CG in the bubbler environment was observed when compared to CG of blotter treatments at the same temperatures with approximately 90% of germination in the bubbler occurring within the first week after initiation (Figure 10). The Bubbler18/10C treatment had a CG of 6.6 (the highest in the trial) compared to 3.8 (Blotter18/10C+Blch) and 2.4 (Blotter18/10C). Similarly, the Bubbler22C treatment CG was 14 and 3.5 times greater than the CG of the 22 °C on blotter paper with bleach and without bleach, respectively.

We also observed significant differences in CG based on temperature, as 18/10 °C treatments consistently germinated more quickly than comparable treatments at 22 °C. The Bubbler18/10C treatment had a 40% increase in CG compared to the Bubbler22C treatment. CG in the Blotter18/10C treatment was 1.7 times greater than the Blotter22C treatment, and the Blotter18/10C+Blch was nearly 12 times greater than the Blotter22C+Blch treatment. The lowest temperature (2 °C) had poor germination and a very slow CG (1.0 with bleach and 0.3 without bleach).

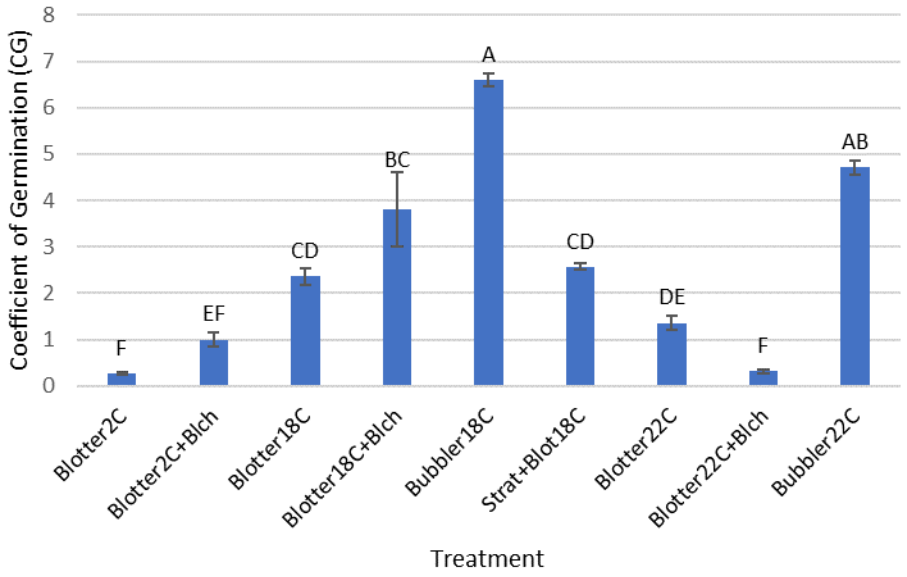

Figure 10. Coefficient of germination (CG) of bristly fiddleneck seedlings after 4 weeks in 2 growing media (blotter and bubbler) and 3 temperatures (2, 18/10, and 22 °C). Larger values indicate a faster germination rate. Error bars are ±1 standard error. Different letters indicate significant differences in mean percent emergence at $p < 0.05$.

Adding a bleach pre-treatment significantly improved CG of seed at 2 °C but not at 18/10 °C. The bleach treatment also caused a significant decrease in CG at 22 °C.

Our results indicate that bristly fiddleneck prefers cool moist conditions for germination with some seeds able to germinate at extremely cold temperatures. Additionally, seed undergoing 2 °C cold/moist stratification germinated upon removal from the cooler . This may be welcome news for restorationists pitting native forbs against cheatgrass and other cold-germinating invasives. Cold-moist stratification was found to be unnecessary in these trials. Germination of non-stratified seed in blotter and bubbler environments was detected in less than 24 hours. Very quick germination and emergence may contribute to this species' competitive advantage against invasives like cheatgrass and red brome (Abella et al., 2011; Leger et al., 2014).

The high germination percentage of 93% suggests that the cleaning protocol used, especially the use of the air column to remove light, non-viable seed, was adequate.

This experiment adds one more species to the list of those known to exhibit improved germination in an aerated water bath compared to a standard blotter paper medium. Higher germination rates and faster, more uniform germination is useful for seed viability testing, greenhouse experiments and containerized production (Tilley and Picket, 2021). Bubblers could be used for synchronized production or a quick means to assess seed viability. Adding a bleach treatment to blotter germinated seed did not result in FG or CG reaching levels obtained in the aerated water bath. Circulating aerated water may provide enough agitation and water flow to wash the seed coat and prevent spores from adhering. This may account for at least some of the increase in FG and CG.

Figure 11. Significantly more seedlings emerged from seed planted very shallow (0 cm). We observed no significant difference in emergence based on soil texture. Photo by Derek Tilley.

Emergence

No significant difference ($P = 0.1567$) was detected in FG by soil texture (Figures 11-12). Nor did we detect a significant interaction factor between soil texture and seeding depth ($p = 0.4035$). Significant differences, however, were observed between soil depths ($p < 0.0001$). Shallow seed placement (0 cm) resulted in significantly better FG and CG scores for all soil textures compared to 1 and 2 cm depths. Germination at 1 and 2 cm did not differ from each other. After 42 days, very few seedlings had emerged from deeper planting depths. This may indicate a possible light requirement for germination agreeing with Forbis (2010), or it may be the result of low seedling vigor. For field and restoration purposes, we recommend surface or very shallow seeding depths.

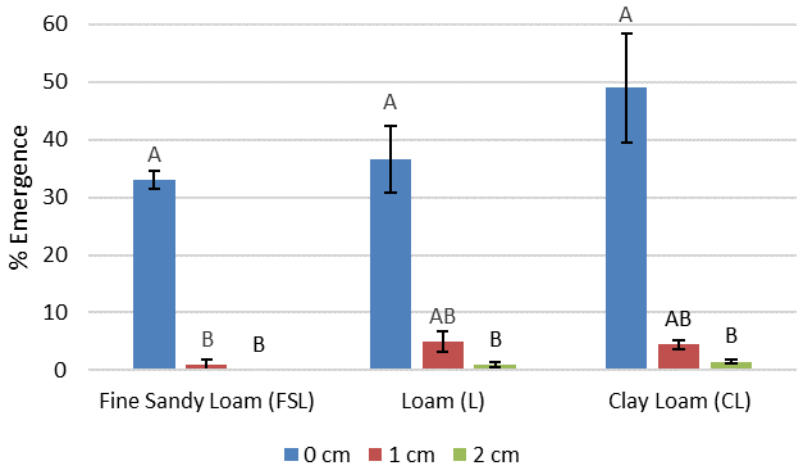

Figure 12. Percent emergence of bristly fiddleneck seedlings after 6 weeks planted at 0, 1, and 2 cm depth in 3 soil textures: fine sandy loam (FSL), loam (L), and clay loam (CL). Error bars are ±1 standard error. Different letters indicate significant differences in mean percent emergence at $p < 0.05$ within soil texture groups.

This experiment only evaluated germination in the various soil textures. Long-term indicators of adaptation such as growth, biomass production and seed production might be affected by soil texture but were not captured in this study.

Agricultural Harvesting
No data were collected during 2023.

CONCLUSION

Our results confirm that bristly fiddleneck readily germinates under laboratory and greenhouse conditions. Quick, synchronized germination is achievable with an aerated water bath environment. We also confirm that this early seral species germinates at lower temperatures supporting the evidence that bristly fiddleneck may have value in recovering disturbed and invaded sites through niche pre-emption (Csákvári et al., 2023) against cool germinating invasive species. Shallow surface seeding is necessary for seedling emergence, and deeper placement resulted in near zero seedlings. Wildland harvesting is feasible for small amounts of seed, but protective gear is strongly recommended to prevent injury and avoid irritation. Information regarding large scale production and harvest will be included in the 2024 final report. Further investigation is needed to determine in row-spacing and plant population density for maximizing seed production. Long-term seed viability testing is also needed to determine shelf storage life and seed banking potential.

LITERATURE CITED

Abella SR, Craig DJ, Chiquoine LP, Prengaman KA, Schmid SM, Embrey TM. 2011. Relationships of native desert plants with red brome (*Bromus rubens*): toward identifying invasion-reducing species. Invasive Plant Science and Management 4:115-124.

Agneray AC, Parchman TL, Leger, EA. 2022. Phenotypes and environment predict seedling survival for seven co-occurring Great Basin plant taxa growing with invasive grass. Ecology and Evolution 2022;12:e8870.

Ballard M., Hough-Goldstein J, Tallamy D. 2013. Arthropod communities on native and nonnative early successional plants. Community and Ecosystem Ecology 42(5): 851-859.

Barak RS, Fant JB, Kramer AT, Krissa A. 2015. Assessing the value of potential "native winners" for restoration of cheatgrass-invaded habitat. Western North American Naturalist. 75(1):58-69.

Bushman BS, Johnson DA, Connors, KJ, Jones, TA. 2015. Germination and seedling emergence of three semiarid western North American legumes. Rangeland Ecology and Management 68(6): 501-506.

Chambers JC, Roundy BA, Blank RR, Meyer SE, Whittaker A. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs 77: 117–145.

Christie K, Pierson NR, Lowry DB, Holeski LM. 2022. Local adaptation of seed and seedling traits along a natural aridity gradient may both predict and constrain adaptive responses to climate change. American Journal of Botany 109: 1529-1544.

Csákvári E, Sáradi N, Berki B, Csecsertis A, Cseperke Csonka, A., Paolinelli RB, Török K, Valkó O, Vörös M., Halassy M. 2023. Native species can reduce the establishment of invasive alien species if sown in high density and using competitive species. Restoration Ecology 31(5): e13901.

Curran M, Sorenson JR, Craft ZA, Crow TM, Robinson TJ, Stahl PD. 2022. Ecological restoration practices within a semi-arid natural gas field improve insect abundance and diversity during early and late growing season. Animals 13(1): 134.

Davison J. 2003. A field guide for collecting native seeds in Nevada. University of Nevada Cooperative Extension.

de Queiroz T, Swim S, Turner PL, Leger EA. 2021. Creating a Great Basin native annual forb seed increase program: lessons learned. Native Plants Journal 22(1): 90-102. doi:10.3368/npj.22.1.90
Discover Life. 2023. https://www.discoverlife.org/mp/20q?search=Amsinckia+tessellata&m_i=t (accessed 3 August 2023).
Forbis T. 2010. Germination phenology of some Great Basin native annual forb species. Plant Species Biology 25: 221-230.
Humphrey LD, Schupp EW. 2001. Seedbanks of *Bromus tectorum* dominated communities in the Great Basin. Western North American Naturalis 61:85-92.
Jensen S. 2004. Racquets, hoppers, and felt boards--low-tech devices for processing seeds. Native Plants Journal 5(1): 50-51.
Leger EA, Goergen EM, Forbis de Queiroz T. 2014. Can native annual forbs reduce *Bromus tectorum* biomass and indirectly facilitate establishment of a native perennial grass? Journal of Arid Environments 102:9-16. doi:10.1016/j.jaridenv.2013.10.015
Luna T, Wilkinson K, Dumroese KR. 2009. Seed germination and sowing options. In: Dumroese KR., Luna T, Landis T, eds. Nursery manual for Native Plants: A Guide for Tribal Nurseries - Vol 1: Nursery Management. Agriculture Handbook 730. Washington, D.C. U.S. Department of Agriculture, Forest Service. p. 133-151.
McCormick ML, Carr AN, DeAngelis P, Olwell M, Murray R, Park M. 2021. National seed strategy progress report, 2015-2020. USGS, Southwest Biological Science Center. 80p.
Maguire JD. 1962. Speed of germination--Aid in selection and evaluation for seedling emergence and vigor. Crop Science 2:176-177.
Mahood AL, Balch JK. 2019. Repeated fires reduce plant diversity in low-elevation Wyoming big sagebrush ecosystems (1984-2014). Ecosphere 10(2):E02591. 10.1002/ECS2.2591
Ogle DG, Tilley D, St. John L, Stannard M, Holzworth L, Wolf M. 2023. Plant Materials Technical Note 24: Conservation Plant Species for the Intermountain West. USDA Natural Resources Conservation Service, Aberdeen, ID. 76 p.
Perry LG, Cronin SA, Paschke MW. 2009. Native cover crops suppress exotic annuals and favor native perennials in a greenhouse competition experiment. Plant Ecology 204(2):247-259. doi:10.1007/s11258-009-9588-1
Pilliod DS, Welty JL, Arkle RS. 2017. Refining the cheatgrass-fire cycle in the Great Basin: precipitation timing and fine fuel composition predict wildfire trends. Ecology and Evolution 7: 8126-8151.
Pokorny ML, Sheley RL, Zabinski CA, Engel RE, Svejcar TJ, Borkowski JJ (2005) Plant Functional Group Diversity as a Mechanism for Invasion Resistance. Restoration Ecology 13(3):448–459.
Rawlins JK. Anderson VJ, Johnson R, Krebs T. 2009.Optimal seeding depth of five forb species from the Great Basin. Native Plants Journal 10(1): 32-42.
Ray PM, Chisaki HF. 1957. Studies on *Amsinckia*. II. Relationships among the primitive species. American Journal of Botany 44(6): 537-544.
Shaw NL, Lambert SM, DeBolt AM, Pellant M. 2005. Increasing native forb seed supplies for the Great Basin. In: Dumroese RK, Riley LE, Landis TD. (Eds.), National proceedings: Forest and Conservation Nursery Associations—2004; 12–15 July 2004; Charleston, NC, USA; and 26–29 July 2004; Medford, OR, USA. Proceedings RMRS-P-35. Fort Collins, CO, USA: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, pp. 94–102 (technical coordinators).
Simonson DB, Tilley DJ. 2016. A low-cost modification to a Flail-Vac harvester for collecting lightweight, wind-dispersed seed. Native Plants Journal 17(2): 103-108.

Simonson DB, Cornforth B, Ogle D, St. John L. 2006. Plant Materials Technical Note 25: Function and operation of a machine to lay weed barrier fabric. USDA Natural Resources Conservation Service, Aberdeen, ID. 8 p.
Tilley D. 2013. Soaking Nebraska sedge seeds in warm, aerated water improves germination. Native Plants Journal 14(1):55-58.
Tilley D, Pickett T. 2021. Germination response of curlycup gumweed to oxygenated water treatment. Native Plants Journal 22(1): 4-12.
Tilley D, Taliga C, Bair C. 2018. Case study of in situ harvesting in restored grasslands to increase native seed availability. Native Plants Journal 19(2): 109-116.
Tilley D., Hulet A., Bushman S., Goebel C, Karl J., Love S, Wolf M. 2022a. When a weed is not a weed: succession management using early seral natives for Intermountain rangeland restoration. Rangelands https://doi.org/10.1016/j.rala.2022.05.001.
Tilley D, Wolf M, Jolley D, Hirning G. 2022b. Seedling emergence and seed production of curlycup gumweed. Native Plants Journal 23(3): 299-308.
Tilman D, Downing JA. 1994. Biodiversity and stability in grasslands. Nature 367 (27): 363-365.
[USDA NRCS] U.S. Department of Agriculture, Natural Resources Conservation Service. 2023. The PLANTS database. URL: http://plants.usda.gov (accessed 19 July 2023). Goldsboro (NC): National Plant Data Team.
Uselman SM, Snyder KA, Leger EA, Duke SE. 2015. Emergence and early survival of early versus late seral species in Great Basin restoration in two different soil types. Applied Vegetation Science 18: 624-636.
Welsh, SL, Atwood ND, Goodrich S, Higgins LC. 2003. A Utah Flora. Third Edition, revised. Brigham Young University, Provo (UT). 912 p.
Winters D. 2023. Personal communication. L&H Seed. Connell, WA.

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