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Seedling Emergence and Seed Production of Curlycup Gumweed

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ABSTRACT

Native Intermountain rangeland forbs are in demand among restorationists but are underrepresented in revegetation projects due to high seed cost, limited availability, and poorly understood establishment requirements. Curlycup gumweed (*Grindelia squarrosa* (Pursh) Dunal [Asteraceae]) is a short-lived forb, native to semiarid sites in the Intermountain West with potential for broad scale use in restoration activities. We conducted a glasshouse experiment examining seedling emergence of curlycup gumweed planted at depths of 0, 1, and 2 cm in three different soil textures (sand, loam, and clay loam). We also compared 3 seed harvest methods of curlycup gumweed in a replicated field trial and evaluated seed yield, purity, and viability. In a third experiment, we tracked viability of seed stored in dry, cool conditions over 3 years using tetrazolium (TZ) staining. Our seedling emergence experiment indicated that maximum emergence can be achieved by planting seed on the soil surface (0 cm) regardless of soil texture. Soil texture had no effect on seedling emergence at any depth. Seed yields from harvesting once via mechanical swathing, simulated using a hedge clipper, were comparable to yields from multiple hand harvests using a racquet-and-hopper, while harvesting with a Flail-Vac resulted in poor yields. Average seed purity and viability did not differ among harvesting methods. Finally, seedling vigor changed little under storage conditions and stayed above 95% over 3 years. Our results suggest curlycup gumweed has excellent potential for larger scale seed production and marketability.

Key Words

forb, harvest, seeding depth, seedling vigor

Nomenclature

USDA NRCS (2018)

INTRODUCTION

Native forbs have been shown to be a critical component of Intermountain Western habitats, and diverse assemblages of native forbs are often desired for restoration and reclamation plantings. Forbs provide a food source for wildlife and pollinator species (Dumroese et al., 2016), they add ecological resilience against invasion (Pokorny et al., 2005; Leger et al., 2014) and can influence soil chemical properties and nutrient availability (McLendon & Redente, 1992). Additionally, successional management, the practice of including species from multiple successional stages in restoration plans, is bringing new and poorly understood native forbs into consideration for restoration plantings (Uselman et al., 2015; de Quieroz et al., 2021). Yet despite their value, native forb use in seed mixes has been historically limited in revegetation projects because of high seed cost, limited availability, and poor establishment (Shaw et al., 2005). Information regarding forb germination and production characteristics is needed to increase establishment rates and seed availability among species of this functional group.

Seed depth, or seed placement, can be critical to achieve desirable establishment, especially with native forbs (Sanderson & Elwinger, 2004; Rawlins et al., 2009; Bushman et al., 2015). Generally, seed placed deeper in the soil is often better protected against herbivory, desiccation, and temperature fluctuations; however, there is a limit to seedling vigor, that is, the force a germinant has at its disposal to penetrate the soil surface. Seed placed too deep may germinate but not have the power to break through the soil or soil crust. A rule of thumb used by horticulturalists and gardeners is to place the seed to a depth equivalent to 2 to 3 times the width of the seed (Vanderlinden, 2019).

For many small-seeded native forbs and grasses, that may be very close to the soil surface. Further complicating the issue is variation in soil texture, or the percentage of sand, silt, and clay in a soil. Soil texture determines differences such as bulk density, porosity, water infiltration, and susceptibility to compaction or crusting. Thus, seed of a certain species may have a different optimum seed depth for any given soil texture (Rawlins et al., 2009; Bushman et al., 2015). Understanding seeding depth is crucial to restoration and seed production efforts.

Determining optimal seed production methods for a given species is an important factor in seed availability and cost. Efficient harvesting increases seed availability and reduces cost for the producer and end user. Native forb seed is often expensive compared to grasses, and high seed cost can be a limiting factor in forb seed use in restoration efforts (Richards, 1998). Many native forbs require specialized production techniques and are only produced in small quantities (Bartow, 2014; de Quieroz et al., 2021). For example, seed of some species, such as shy gilia (*Gilia inconspicua* (Sm.) Sweet [Polemoniaceae]) may be most effectively harvested by hand or by uprooting the entire plant and provide yields of less than 100 kg/ha (89 lb/ac) (de Quieroz et al., 2021). Seed of other species may be collected by allowing the seed to shatter in place and picking up the seed from the ground with brushes or vacuums (Bartow, 2014). Many native forbs however possess attributes that are better suited to large scale agronomic production. Western yarrow (*Achillea millefoilium* L. [Asteraceae]) and firecracker penstemon (*Penstemon eatonii* A. Gray [Scrophulariaceae]) seed yields, for example, can range in the hundreds of kg/ha (Cornforth et al., 2001).

Seed viability under storage conditions is a further factor in seed availability and cost. Seed with a short shelf life must be sold quickly to avoid losses in viability and seed producers may hesitate to risk producing more seed than can be sold within the seed's life span. Some species used in the Intermountain West like sagebrush (*Artemisia tridentata* Nutt. [Asteraceae]) and forage kochia (*Bassia prostrata* (L.) A.J. Scott [Chenopodiaceae]) have very short storage life spans (Karrfalt & Shaw, 2013; Kitchen & Monsen, 2001). Others like Indian ricegrass (*Achnatherum hymenoides* (Roem. & Schult.) Barkworth [Poaceae]) have very long shelf lives, losing little viability over many years (Jones & Nielson, 1992). Seed that maintains high viability in long-term storage ameliorates the effects of "boom or bust" seed sales common in the wildfire-driven seed market of the western United States. Understanding a species' viability under storage conditions can assist producers and storage facilities in optimizing stocking rates and limiting waste.

Curlycup gumweed is a native forb under investigation for use in various western rangeland applications including sage-grouse and pollinator habitat enhancement, vegetative fuel breaks (Tilley & Wolf, 2020), oil and gas reclamation, and general restoration (Tilley & Pickett, 2019). It often functions as an early seral or ruderal species which may offer greater ability to compete with weeds and increase site resilience to invasion when used in the context of succession management (Tilley et al., 2020). Curlycup gumweed has also been shown to have potential as a source of biofuel (Neupane et al., 2016). This species seemingly displays many characteristics beneficial to agronomic production, namely upright growth, limited seed shatter, and potential high seed yields; however, it has to date only been collected in limited quantities and larger-scale production methods have yet to be explored.

Gumweed is described in the taxonomic literature as a biennial to short-lived perennial that forms a basal rosette in the first growing season and produces flowers and fruit in its second year of growth

(Harrington, 1954; Welsh et al., 2003). The species rarely produces seed of significant amounts during the first (rosette) year and is unlikely to persist a third season. It will therefore, in effect, only produce one seed crop within its 2-y life span before a seed producer will have to plant a new field. In comparison, annual seed crops produce seed in the same year planted, while perennial crops (most restoration grasses and forbs) are longer-lived and produce crops for several years before needing to be re-planted. Biennials have a distinct disadvantage for producers in that they will only produce seed in half of the growing year, so maximizing harvest yields and efficiency is critical.

Additional research is needed to improve establishment of native forbs in seed production fields and on rangeland sites. Research is also needed to evaluate production methods to increase seed availability and to reduce the cost to the end user. We established a glasshouse experiment to evaluate curlycup gumweed seedling emergence from various depths and soil composition and a field trial comparing three seed harvesting methods. In a third experiment we tracked seed viability of curlycup gumweed seed lots for 3 years to observe any decreases in viability under storage conditions.

MATERIALS AND METHODS

Seeding Depth and Soil Type

The purpose of the first experiment was to evaluate seedling emergence from 3 seeding depths in soils of various composition. Soils of three texture classes were collected from sites in Southern Idaho including a Quincy fine sand (S), Declo loam (L) and a Fingal clay loam (CL) (USDA Soil Survey, etc). The soil was sieved to remove any large aggregates, rocks, or plant matter, and the sieved soil was placed into 50 x 25 x 5 cm plastic trays. Three accessions of curlycup gumweed from native stands in Idaho, Nevada and Utah representing three Level III Ecoregions (Omernik, 1987)- possible surrogates for seed transfer zones (Miller et al., 2011; Bower et al., 2014) (Table 1, Figure 1) were threshed and cleaned at the USDA-NRCS Plant Materials Center at Aberdeen, Idaho (IDPMC). Seeds were tested for viability at the Idaho State Seed Laboratory (ISSL) using tetrazolium (TZ) staining on 200 seeds from each accession prior to experimentation. All 3 accessions were blended in equal amounts and then pre-treated by soaking the seed in an oxygenated water bath for 24 h following Tilley and Pickett (2020) to overcome seed dormancy and initiate germination. We placed seeds in a fine mesh bag and submerged them into a 0.95 L mason jar filled with 500 mL distilled water. Air was added using a Profile 1500 aquarium air pump fitted with a 2.5 cm bubbling air stone. The soaked seeds were immediately planted in each of the soils after soaking and buried to a depth of 0, 1 or 2 cm. Each treatment consisted of 36 seeds planted in 3, 15 cm rows at approximately 1 cm spacing. The experiment was set up in a randomized complete block design with 6 replications in a glasshouse in Aberdeen, ID. The trays were watered every other day for 20 min. We evaluated total seedling emergence after 5 wk. Seedlings were counted as “emerged” if the cotyledon, seed coat, or hypocotyl were visible.

Table 1. Seed Source Information for 3 seed accessions used in the seedling emergence experiment. All accessions were blended in equal amounts before seeding and pre-treated in an oxygenated water bath to break dormancy.

Accession #	Location	Level III Ecoregion (Omernik 1987)	Native Soil	Elev. (m)
9106656	42.430 N, 112.180 W	Northern Basin and Range	Downey-Arimo complex gravelly silt loam	1,470
9106675	41.166 N, 117.682 W	Central Basin and Range	Enko very fine sandy loam	1,370
9106671	40.487 N, 109.558 W	Colorado Plateau	Robido-Uver complex loam	1,650

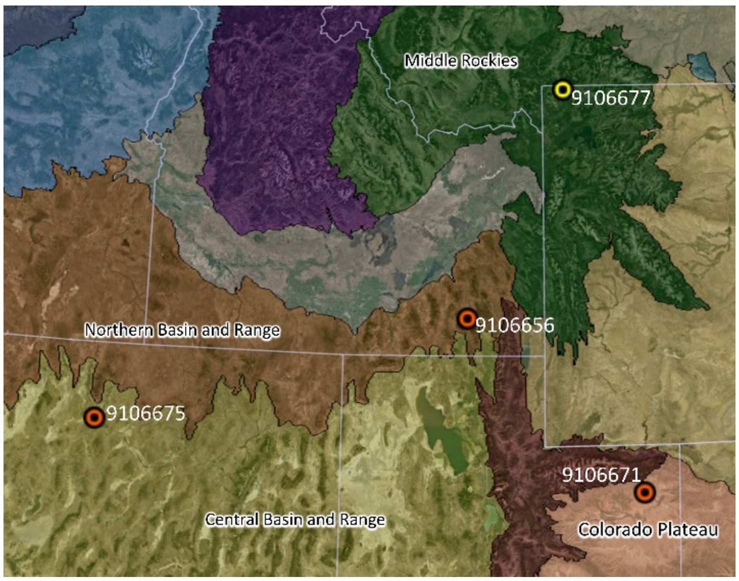

Figure 1. Locations of 3 seed collection sites for seeding depth study (red marker) and collection site of seed used for the seed harvest study (yellow marker). Level III Ecoregions of the collection sites are highlighted (US EPA 2013). Satellite imagery courtesy of Google Earth.

Seed Harvest

In the second experiment we evaluated 3 commonly used seed harvesting techniques on a seed production field of curlycup gumweed. Wildland collected seed of accession 9106677 originating from the Gardiner Basin of Yellowstone National Park (Frontispiece) was established in a field at IDPMC in the fall of 2020. The production field was 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). We burned 10 cm (2 in) holes into the center of the fabric every 46 cm (18 in) and planted 5 to 10 seeds at a depth of 0 to 5 mm in each hole. The experiment was a randomized complete block design with 4 replications. The fabric strip was divided into 12.2 m long plots, each containing approximately 26 plants. For yield analysis the plots were considered to be 1 m wide x 12.2 m long (12.2 m^2) based on commonly used 1 m (36 in) row spacing (Cornforth et al., 2001; Simonson & Tilley, 2016). The field received 5 cm (2 in) of irrigation on May 7 and again on June 11 during the 2020 growing season. No supplemental water was applied during 2021. The plants in our production field were visibly larger than those encountered at the collection site. At the time of harvest our plants were on average 61 to 69 cm (24 to 27 in) tall and approximately 120 cm (48 in) wide.

Three harvesting methods were evaluated, 1) swathing, 2) racquet-and-hopper, and 3) Flail-Vac. Swathing and combining is a preferred seed harvesting method as it allows seed to ripen and cure on the cut stems and reduces seed loss from shattering that may occur when harvesting ripe materials. 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; St. John et al., 2010). Flail-Vac harvesters (Woodward Flail-Vac Seed Stripper, Ag-Renewal Inc, Weatherford, OK) are commonly used in native forb and grass seed production (Keys, 2006; Simonson & 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 as the nylon brushes in the header whip the plants at high speeds to remove the seed resulting in significant damage to mature and unripe flowers (Simonson & Tilley, 2016).

Figure 2. An electric hedge trimmer was used to simulate a swathing operation. Cut material was placed on tarps to dry in lieu of windrowing.

Swathing was simulated using a Black & Decker® 40 cm (16 in) electric hedge trimmer (Hunt Valley, MD) powered by a portable generator (Figure 2). Stems were cut approximately 10 cm below the flowers and the cut material was placed by hand on tarps to dry. Clipping for the swathing treatment was conducted on September 12, 2021, when the first flowers were just beginning to shatter to allow for post-harvest ripening.

The racquet-and-hopper harvest was done using a badminton racquet and a home-made 1 m diameter hoop with nylon catch hopper. Flower heads were beaten to capture as much seed as possible as flowers ripened indeterminately (Figure 3). Seed that was ripe and ready to dehisce, readily shattered off into the hopper, while unripe seed remained on the seed heads. To maximize seed yields, we conducted racquet-and-hopper harvests on September 17, 22, 26 and 30.

Figure 3. Seed collecting using a badminton racquet and a canvas hopper is common for gathering wildland forb seed. Beating effectively removes ripe seed while leaving the unripened flowers intact for additional harvests. Four racquet-and-hopper harvests were conducted in our trial as seed heads ripened to maximize yields.

Flail-Vac harvesting occurred on September 22 and again on October 6. Our apparatus was run with a brush speed of 400 RPM and tractor speed of 1.9 km/h (1.2 mph). The Flail-Vac head was placed as deep as possible into the flower canopy, sitting approximately 10 to 20 cm (4 to 8 in) from the ground (Figure 4). We repeatedly adjusted the angle of the Flail Vac head to maximize the number of flowers making contact with the brush. Despite our efforts we found it difficult to get the rigid plant stems into contact with the brush as they were pushed forward by the front of the brush shroud but did not bounce back into the brush. We were also unable to harvest seed on stems that were horizontal or those that had fallen due to lodging.

Figure 4. A Woodward Flail-Vac was used twice to harvest seed. We experienced difficulties in getting the flower heads into the opening to the brush as the plants were pushed over by the front of the apparatus despite adjusting the intake angle. Plant lodging further complicated Flail-Vac harvesting.

All harvested material collected by each treatment method was dried on a clean shop floor for 5 to 7 days and then cleaned identically with two cycles through a Westrup air screen cleaner (Slagelse, Denmark) with a 2.1 mm top screen and a 1.15 mm bottom screen. Light air was applied to remove inert and empty seed. Because the harvesting treatments were conducted at different stages of maturation and ripeness, and because each method may favor collecting of seeds of certain size or weight, seed samples from each treatment were sent to ISSL for TZ and purity analysis. Random 0.23 kg (0.5 lb) samples from each plot were sent to ISSL and tested for viability as described for the previous experiment. The seed harvests were additionally analyzed for purity using 3 g subsamples.

Viability Over Time

In our third experiment, we tested seed viability under storage conditions. Curlycup gumweed seed originally collected in 2018 was held in storage at IDPMC at low temperatures (10 to 13 °C) and low relative humidity (10 to 50%). We analyzed seed viability over time as a completely randomized design with 5 replications of randomly selected samples sent to ISSL. Seed was first tested in 2018 (yr-0) and was then tested again in 2019 (yr-1) and 2021 (yr-3).

Experimental Analysis

Data for all 3 experiments were tested for normality using a Shapiro-Wilk test to determine the appropriate test to analyze variance. Analysis of variance for the seedling emergence experiment was assessed using the Factorial AOV procedure of Statistix 10 Analytical Software (Tallahassee, FL) with depth and soil type selected as factors. Seed harvest yield and purity data were determined to be normally distributed and were analyzed for variance using a one-way AOV followed by means separation using the Tukey HSD test at a $P<0.05$ level of significance. Seed viability data for the harvest experiment and the viability over time experiment were not normally distributed and were thus analyzed using a Friedman nonparametric two-way AOV with viability selected as the dependent variable and replication and treatment set as the categorical variables.

RESULTS AND DISCUSSION

Seeding Depth and Soil Type

Laboratory testing prior to the seeding depth experiment indicated viability of >96% of all seed lots used. The Factorial AOV found no significant effect from soil texture (P=0.4783), but we did see a significant effect from soil depth on seedling emergence (P=0.0000). We also detected no significant interaction of soil and depth on emergence (P=0.1647).

Figure 5. Seeding depth of emergence was evaluated in 3 soil textures (fine sand, loam, and clay loam) at 3 depths (0, 1, and 2-cm). Image taken at 4 wk after planting.

In the S soil, the 0 cm planted seed had 42% emergence, significantly higher than emergence from the other 2 seeding depths (Figure 6). Percent emergence of seed planted at 1 and 2 cm in S soil (24 and 26%, respectively) did not differ significantly. The highest percent emergence in the L soil (47%) was likewise achieved by the 0 cm planted seed. This was not significantly higher than the 1 cm planted seed which had a percent emergence of 32%; however, the deeper, 2 cm planted seed had the lowest percent emergence in the L soil with 17% emergence which was significantly lower than the 0 cm depth. In the CL soil, we again observed the highest emergence in the 0 cm planted seed with 38%, followed by the 1 and 2 cm planted seed with 26 and 22% emergence, respectively.

We saw no significant differences among average percent emergence based on soil texture of 0 cm planted seed. Emergence ranged from 38% in the CL soil to 47% in the L soil. At the deeper soil depths, there were no differences in emergence based on soil composition. Seed planted at 1 and 2 cm in CL or L did not result in lower germination than seed planted at the same depth in S. Based on these results, curlycup gumweed should be recommended for planting via broadcast seeding or very shallow drill seeding near the soil surface. If curlycup gumweed is included in a seeding mix that is drill seeded at greater depths to accommodate other species, lower rates of gumweed establishment can be expected. Our data further suggest that curlycup gumweed can be successfully seeded on a wide range of soil types with no difference in expected early establishment.

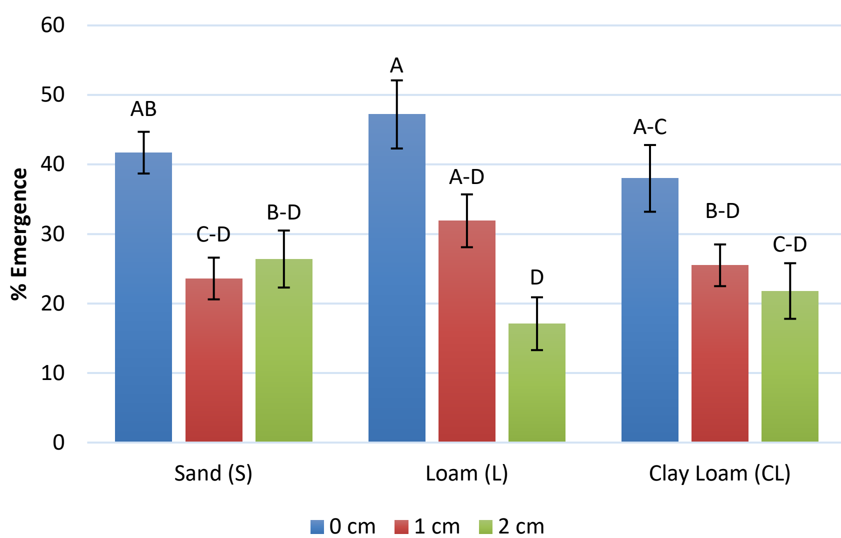

Figure 6. Percent emergence after 5 wk of curlycup gumweed seed planted at 0, 1, and 2 cm depth in 3 soil textures: sand (S), loam (L), and clay loam (CL). Error bars are ±1 standard error. Different letters indicate significant differences in mean percent emergence at *P<0.05*.

Maximum emergence after 5 wk in our trial was 47%. This is much lower than the percent viable seed indicated by laboratory TZ testing; however, these results are similar to findings reported by Tilley and Pickett (2021) and Luna (2008) and suggest that seed dormancy is not fully overcome by soaking in oxygenated water or by 60-d cold-moist stratification. Better germination rates may be achievable in field settings using fall-dormant seedings to achieve natural stratification with numerous temperature and moisture fluctuations.

Seed Harvest Methods

Seed yields from the swathing and the racquet-and-hopper harvest methods were significantly greater than yields obtained using a Flail-Vac harvester (*P=0.0498*). Swathing and racquet-and-hopper harvests averaged yields of 1,525 and 1,509 kg/ha, respectively. These two harvest methods collected approximately 6 times more seed than the Flail-Vac harvesting which yielded an average of 233 kg/ha (Figure 7).

We used hedge trimmers to simulate a swathing operation in our experiment. Swathing and wind-rowing curlycup gumweed prior to ripening and allowing the seeds to ripen on the cut stems before combining may be feasible on a farm scale. This method would allow the seed to fully ripen while in windrows and reduce losses from seed shatter. The vegetative and floral material was notably sticky at the time of swathing while much of the plant was still green. However, drying in windrows (on tarps in our experiment) reduced the stickiness significantly and this was not an issue during seed processing.

The Flail-Vac harvester was ineffective at collecting seed of curlycup gumweed. The brush machine tended to wrap any green and flexible plant material around the brush, yanking the plants entirely out of the ground. Most of the seed heads were pushed away from the brush, even with the Flail-Vac lowered down into the canopy. We attempted to improve seed pickup by using chains as demonstrated by Simonson and Tilley (2016) to help push the outer stems upward into path of the Flail-Vac, but that was also unsuccessful. A modification to the Flail-Vac similar to corn lifters might yield better results.

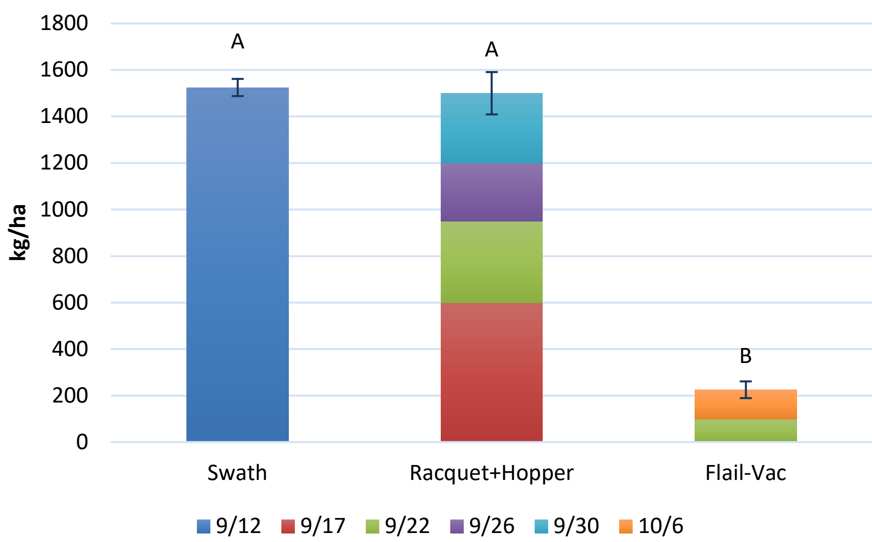

Figure 7. Extrapolated seed yield (kg/ha) of curlycup gumweed grown on weed barrier fabric harvested with hedge clippers (swath), racquet-and-hopper, and Flail-Vac. Plot size was 1x12.2 m. Different colors indicate different harvest dates. Different letters indicate significant differences at *P<0.05*. Error bars represent ± 1 standard error. For lb/ac multiply by 0.89.

Figure 8. Stem lodging was present in many of the harvested plants and was a significant problem for the Flail-vac harvest.

Plant lodging, possibly exacerbated by increased soil moisture under the weed barrier fabric, reduced uptake by the Flail-Vac, but even when plants remained upright, the Flail-Vac performed poorly. Lodging did not have as great an effect on the swathing and racquet-and-hopper harvest methods. Swathing was done early before stems had weakened from drying, while the hopper could easily be slid under the fallen stems when capturing seed.

Seed yields will vary widely depending on row spacing and plant density. Our yield data are based on extrapolations of 12.2 m^2 plots, with a single row of plants spaced every 46 cm. Intermountain forb seed production spacing practices vary widely from 0.6 m (24 in) (Stevens et al., 1996; Simonson & Tilley, 2016) to 2 m (6 ft) spacing of individual fabric rows. Though not directly comparable, our yields for curlycup gumweed far exceed typical yields for commonly grown native forbs such as western yarrow and firecracker penstemon which average 170 to 225 kg/ha (150 to 200 lb/ac), respectively (Cornforth et al., 2001).

The use of weed barrier fabric likely affected our seed yields. We saw increased soil moisture retention directly below the weed barrier fabric. This was likely the cause of increased plant size and lodging compared to parent populations and possibly resulted in an increase in the number of stems and flowers per plant. Therefore, some addition of water even for such a drought tolerant species, may increase seed yields under agronomic conditions, as has shown to be the case with other Intermountain forbs (Shock et al., 2015).

The cleaning protocols described in the materials and methods section resulted in excellent viability and high levels of seed purity from all 3 harvesting methods (Figure 9). Seed viability measured using TZ staining ranged from 95.3 to 97.3% and did not differ significantly between harvesting treatments when cleaned in the same manner (*P=0.2177*). Despite the swathing treatment being conducted a minimum of 5 d before other harvesting treatments while stems were green and seed had not yet shattered, post-harvest ripening allowed seed to fully mature with no discernable reduction in viability. Seed purity ranged from 94.0 to 96.0% with no statistically significant differences apparent between harvesting methods

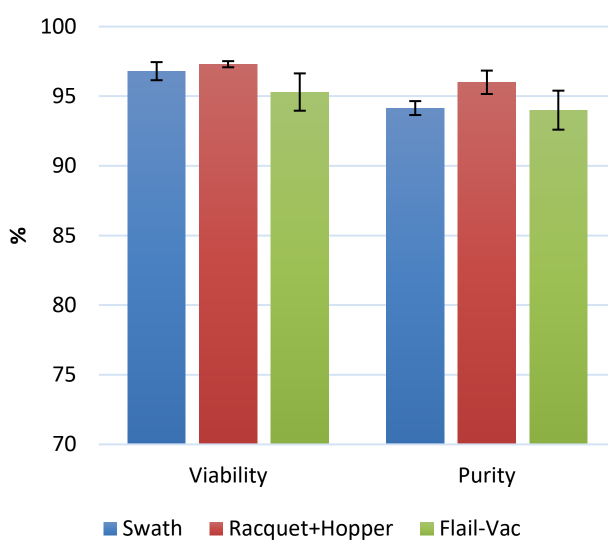

Figure 9. Percent viability and purity of processed curlycup gumweed seed harvested via swathing, racquet-and-hopper, or a Flail-Vac. No significant differences were detected between means. Error bars represent ± 1 standard error. Note: Y axis ranges from 70 to 100%.

(*P=0.4454*). Impurities in the seed lots were characterized as broken seed, chaff, plant debris, and soil.

We did not track or compare labor hours per kg of seed harvested in our study, but the differences in labor for each method are significant. Racquet-and-hopper harvesting is very effective for small operations; however, it requires multiple harvests for maximum yield. It is also the most labor-intensive harvest method tested here, as it is entirely done by hand. Flail-Vac harvesting is fully mechanized and is thus considerably faster over larger areas but was shown in this study to be less effective at optimizing seed yields. Swathing is likewise mechanized but takes two operations - swathing followed by combining of the dried rows. Based on our results, swathing and combining would appear to be the most efficient means of harvesting curlycup gumweed seed under agronomic conditions.

Viability Over Time

We compared laboratory TZ results of curlycup gumweed seed over 3 years in cool-dry storage conditions. We saw no discernable changes in seed viability after the first year of testing. Viability at the year of harvest (2018) and after 1 year of storage (2019) averaged 97.6%. After 3 years (2021) mean viability had increased according to lab test results to 98.0%, but we found no significant differences between years (*P=0.2303*). Long term viability of curlycup gumweed seed could be related to its significant seed dormancy and its functioning as an early seral species. The species can sit in place in the seed bank for extended periods of time waiting for disturbance before germination. While these tests do not offer any long-term viability data for curlycup gumweed, short term storage viability trends are promising. If these trends continue, curlycup gumweed seed may retain acceptable levels of viability for many years under proper storage conditions.

CONCLUSION

Forb seed is in demand by land managers and the public in the Intermountain West for habitat improvement and biodiversification plantings. However, limitations in seed availability and disappointing establishment rates have prevented broad scale use of this species group (Shaw et al., 2005). Reliable production methods and optimum seed placement data are critical to increasing the successful use of forb seed. The native biennial forb, curlycup gumweed, is promoted for rangeland restoration seedings and is being investigated as a biofuel source. Understanding optimum seeding and harvesting practices are key to production and therefore adoption in these industries. Our glasshouse experiments indicate that curlycup gumweed should be seeded at surface or very shallow depths for maximum seedling emergence on all soil types. Field harvesting evaluations show that greatest seed yields can be obtained from multiple racquet-and-hopper harvests or with a single swathing operation followed by combining. The Flail-Vac harvester was ineffective at seed harvesting, mostly due to difficulties in getting the seed heads into the brush area. Short-term seed viability evaluations indicate that curlycup gumweed maintains high levels of viability for at least 3 years under cool-dry storage conditions. The high seed yields we recorded, and the apparent seed storage longevity, suggest that curlycup gumweed could be a marketable species for native seed producers.

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