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Augmenting Populations of Spalding's Catchfly (*Silene spaldingii*) Populations in Northwest Montana

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Spalding's catchfly (*Silene spaldingii*, Caryophyllaceae) is considered threatened throughout its range in the Columbia Plateau under the U.S. Endangered Species Act (USFWS 2007). Many populations, especially in the center of the range are small and will need to increase in size in order to attain recovery. Natural recruitment of Spalding's catchfly is sporadic at some sites (Lesica 1997), and inbreeding may predominate in small populations (Lesica 1993, Baldwin and Brunsfeld 1995), both factors that can lead to lowered population growth. Human-mediated population augmentation can result in more rapid population growth by directly adding individuals and indirectly reducing inbreeding depression (Guerrant 1996).

Transplanting seedlings is often a more successful reintroduction strategy than sowing seeds directly (Guerrant and Kaye 2007, Reckinger et al. 2010, Godefroid et al. 2011, Albrecht and Maschinski 2012). Unfortunately little is known about establishing nursery-grown stock of Spalding's catchfly. Cold-stratification enhances germination of catchfly seed (Lesica 1993), but protocols for post-germination culture have not been developed. The purpose of this study was to develop restoration protocols for Spalding's catchfly usable in Montana and adaptable in other portions of the species range. In particular, we determined how five factors affect survival and growth of nursery-grown stock in the field: (1) age of outplanted seedlings; (2) soil type used in culture; (3) watering in the field; (4) type of nursery container; and (5) date of outplanting.

Spalding's catchfly is a long-lived iteroparous herb with one or few vegetative or flowering stems arising from a caudex surmounting a long taproot (Hitchcock and Maguire 1947). Plants flower in late June through August and set seed in August and September, depending on location. Rosettes are formed the first years after germination after which vegetative stems are produced. Vegetative and flowering plants emerge in mid- to late-May and senesce in September. Spalding's catchfly demonstrates prolonged dormancy in which plants do not appear or have only ephemeral, above-ground vegetation for one or more consecutive summers (Lesica 1997). Prolonged dormancy of germinated plants is common, with bouts of dormancy usually lasting 1–2 years (Lesica 1997, Lesica and Crone 2007).

We conducted our study on Wildhorse Island at the southwest end of Flathead Lake, 20 km north of Polson in Lake County, Montana, U.S. (47° 50' N, -114° 12' W) at 985 m in elevation. Vegetation at the study site is grassland dominated by rough fescue (*Festuca campestris*), Idaho fescue (*F. idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum*) with scattered ponderosa pine (*Pinus ponderosa*). Climate is semi-arid with cold winters and hot summers. Mean annual precipitation is 382 mm and mean July maximum and January minimum temperatures were 28.4°C and -6.7°C respectively at Polson (WRCC 2013). Most of the island is natural area in Wildhorse Island State Park.

We collected seeds of Spalding's catchfly for all experiments from the Dancing Prairie population 160 km north of our study site. Seeds were placed in cold stratification in November, and germinants were obtained in mid-January to mid-February. Germinants were raised in potting soil with native grassland innoculum, first in a greenhouse followed by an outdoor garden. We planted seedlings at 1-meter intervals along four permanent 50-meter transects in an area that currently supports a small population of Spalding's catchfly. We mapped survivorship in all four transects between mid-June and early July, 2010 through 2013. Prolonged dormancy (see above) made it difficult to unambiguously assign presence or absence of Spalding's catchfly transplants across all years. Any plant that was present in at least one year between 2010 and 2013 was assumed to be a survivor. Plants observed to be damaged by rodents or ungulates were eliminated from analyses. We used Fisher's exact test of association (GraphPad Software 2013) to determine whether there was a difference in Spalding's catchfly survival across treatments. We conducted three experiments begun in three separate years: 2008, 2009, and 2011.

Experiment 1 (2008)

Spalding's catchfly germinants were transplanted into pots 9 cm wide and 11 cm deep (hereafter 4-inch pots) in mid-February. In May, 96 plants were stratified into two size classes and randomly transplanted into 4-inch pots with one of two potting media: potting soil (Sunshine Mix # 1, Sun Gro Horticulture, Agawam, MA: *Sphagnum*, perelite, lime wetting agent) and compost (humus, worm castings, chicken and bat manure, kelp meal, lime). We transplanted the 96 seedlings on June 9 into the study site, randomly assigned to one of three watering treatments: (1) no water, (2) water three times, (3) water six times at weekly intervals. Each plant scheduled for watering received 1 liter of water.

Six of the Spalding's catchfly plants were dug out by rodents, deer or sheep in the summer of 2008. Twenty-six of the remaining 90 plants survived. Plants that received water were not more likely to have survived than those that did not (p = 0.62), and there was no difference in survival among the watering treatments (p = 0.99). There was a tendency for plants grown in compost to survive better, but this trend was not statistically significant (p = 0.24).

Experiment 2 (2009)

Forty-nine Spalding's catchfly germinants from 2008 and an additional 49 germinants obtained in a similar manner in 2009 were grown in potting soil in 10-cm pots. We planted the 49 first-year and 49 second-year catchfly seedlings on June 1. Plants were randomly assigned to one of two watering treatments: (1) water three times at weekly intervals; or (2) water six times at weekly intervals. Waterings were performed on June 10, June 20, June 27, July 4, July 11, and July 18. Each plant scheduled for watering received 1 liter of water at each watering. Second-year plants that were starting to bolt at the time of planting were pinched back. Each second-year plant scheduled for watering received 1 liter of water.

Second-year plants were much larger than first-year plants at the time of planting. Four of the Spalding's catchfly plants were dug out by rodents or ungulates after planting in 2009. Of the remaining 94 plants, only 12 survived. There was no difference in survival among the different watering treatments or between the two age classes (p = 0.99).

Experiment 3 (2011)

Ninety-nine germinants were transplanted into conetainers (25 cm long with 6 cm-diameter openings at the top) in February. Thirty-three randomly-chosen plants were planted into the field site on each of three dates: May 2, May 30, and October 4. Plants from each planting treatment were placed along the transect lines at 3-meter intervals and given 1 liter of water. Each plant from the May plantings was also watered with 1 liter of water on June 5 and again on June 12. The October plants were not given additional water after planting. Plants transplanted into the field in early October were large and dormant or nearly so.

Fifty-one of the 99 plants survived. There was no difference between transplants made in early May and late May (p = 0.99), but there was a tendency for spring transplants to have survived better than fall transplants, although this difference was not significant (p = 0.21).

Figure 1. Six-month Spalding catchfly seedling in a 25 cm container. Note the white taproot reaching almost to the bottom of the plug.

Across experiments (2008, 2009, and 2011)

Survival of Spalding's catchfly planted in 2008 (29%) was greater than for those planted in 2009 cohort (13%) (p = 0.01). Survival Spalding's catchfly grown in conetainers and planted in 2011 (51%) was greater than that for either the 2008 cohort (p = 0.002) or the 2009 cohort (p < 0.001).

Our results provide no support for a survival advantage of older transplants or providing supplemental water; however, survival was low across treatments so power to detect differences was curtailed. Compost may be a better growth medium than potting soil, but the difference in survival between the two was small and statistically non-significant. May planting fared better than October planting; however, the small non-significant difference between spring and fall planting occurred in a year with above-average spring precipitation, and results may have been different in an average or dry year.

Differences in survival among years are likely to have been caused by either weather and/or planting conetainers. Spring precipitation (April–June) was above average in 2008, well below average in 2009 and above average again in 2011 (WRCC 2013, Table 1). Low survival of Spalding's catchfly transplants in 2009 may well have been due to the dry spring, although additional watering had no discernable effect in either 2008 or 2009. Spring precipitation was similar in 2008 and 2011, so the difference in survival between these two years was more likely due to the use of 25 cm conetainers in 2011 as opposed to the 10 cm deep pots employed in 2008. Spalding's catchfly develops a long taproot which may reach the bottom of the 25 cm conetainer after only six months of growth (Lesica and Divoky observations; Figure 1). Using a 10 cm deep planting conetainer likely curtailed proper root growth and resulted in the plant's inability to obtain adequate moisture during the latter part of the growing season.

Table 1. Spring (April–June) precipitation and percent Spalding's catchfly survival for the three experimental planting years.

Year	Spring precipitation	Survival
2008	152 mm	29%
2009	55 mm	13%
2011	165 mm	51%

We recommend that first-year Spalding catchfly germinants be transplanted into compost-filled conetainers at least 25 cm in length in January or February. Conetainer-grown plants should be transplanted into the field in early spring if a wet spring is anticipated. Otherwise it may be better to plant in mid-autumn to avoid drought-stress. Plants should be watered in upon planting, but supplemental watering is probably not necessary unless the post-planting weather is particularly dry. These recommendations are for populations in northwest Montana, but are likely applicable, perhaps with some modification, to other portions of Spalding's catchfly's geographic range.

Acknowledgements

Stacey Bengston, Bowen Kadis, Becky Lomax, and Nancy Romalov helped with watering and planting. Jerry Sawyer and the Montana Department of Fish, Wildlife and Parks provided logistical support. Funding was provided by the U.S. Fish and Wildlife Service.

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Effect of Season and Number of Glyphosate Applications on Control of Invasive Mexican Petunia (*Ruellia simplex*)

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Effective control measures for invasive species are particularly needed in forested wetland-urban interface locales. Floodplain forest communities occupy a unique niche as a transition between upland and aquatic ecosystems and support botanically rich vegetation communities compared to adjacent habitats (Nilsson and Svedmark 2002). However, urban-bordered floodplain forests are particularly vulnerable to invasion by aggressive non-native species due to alterations in flooding regime, which may then favor invading non-native species (Predick and Turner 2008). Propagule pressure from invasive plant species is also especially high in the wetland-urban interface due to runoff from urban landscape sources (Loewenstein and Loewenstein 2005).

Mexican petunia, (*Ruellia simplex*, Syn. *R. brittoniana*) is a commonly cultivated ornamental herbaceous perennial. Environmental tolerance and abundant seed production have contributed to its spread from urban landscapes into natural areas. It has been documented in parts of Texas, Louisiana, Georgia, Alabama, Mississippi, and South Carolina (USDA-NRCS 2012a), and vouchered in 29 Florida counties (Wunderlin and Hansen 2011). The Florida Exotic Pest Plant Council lists Mexican petunia as a Category 1 invasive species defined as: "altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives" (Florida Exotic Pest Plant Council 2011).

Preliminary research on Mexican petunia in natural areas suggests herbicides may provide control of Mexican petunia (Hupp et al. 2009). When herbicide was applied twice, 120 days apart, all five herbicides evaluated resulted in low percent cover (< 0.5%) 183 days after initial treatment (Wiese et al. 2013). No work has been done, however, to address the efficacy of treatment as a function of application season, or to determine if additional glyphosate treatments are necessary to achieve optimal control of Mexican petunia. Preliminary research found that locations consisting primarily of Mexican petunia cover (75% or greater) pre-treatment shifted to ≥ 50% non-Mexican petunia composition within 6 months of treatment (Hupp et al. 2009) suggesting the potential for native species recovery following control. Establishment of native species likely suppresses further Mexican petunia invasion; Hupp (2007) found that survival of young Mexican petunia seedlings was reduced when native vegetation was present, compared to bare soil.

Our objectives were to evaluate the effects of glyphosate application season and number of applications on 1) control of Mexican petunia, and 2) species composition and quality of resulting post-treatment plant cover.

The study site was located at Paynes Prairie State Preserve, Alachua County, Florida (29°37'21.7" N, 82°19'20.8" W). The site was a bald-cypress (*Taxodium distichum*) dominated floodplain forest habitat with dense stands of Mexican petunia in the herbaceous vegetation layer. The soil was predominantly from the mulat sand (loamy, siliceous, subactive, thermic Arenic Endoaquults) series (USDA-NRCS 2012b). Six 3 × 3 m plots were randomly located on both sides of a branch tributary bisecting the bald-cypress preserve area (12 plots total). Each plot was divided into four 1.5 × 1.5 m subplots designated by permanent markers.

Herbicide application treatments were applied 0, 1, 2 or 3 times to each subplot in one of two application initiation seasons (fall or spring-initiated application). Percent cover of each species present was measured using a modified Mueller-Dombois scale (0 = 0 %, 1 = <1 %, 2 = 1–4 %, 3 = 5–24 %, 4 = 25–49 %, 5 = 50–74 %, 6 = 75–94 %, 7 = 95–100 %; Mueller-Dombois and Ellenberg 1974).