IRRIGATION REQUIREMENTS FOR NATIVE BUCKWHEAT SEED PRODUCTION IN A SEMI-ARID ENVIRONMENT

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Summary

Native buckwheats (*Eriogonum* spp.) are important perennials in the Intermountain West. Buckwheat seed is desired for rangeland restoration activities, but little cultural practice information is available for seed production of native buckwheat. The seed yield of *Eriogonum umbellatum* and *E. heracleoides* were evaluated over multiple years in response to four biweekly irrigations applying either 0, 1, or 2 inches of water (total of 0, 4, or 8 inches/season). Seed yield of *E. umbellatum* responded to irrigation plus spring precipitation in 10 of the 11 years, with 5 to 11 inches of water applied plus spring precipitation maximizing yields, depending on year. Averaged over 11 years, seed yield of *Eriogonum umbellatum* showed a quadratic response to irrigation rate plus spring precipitation and was estimated to be maximized at 232 lb/acre/year by applying 5.4 inches of water with average spring precipitation of 2.8 inches. Over six seasons, seed yield of *E. heracleoides* was responsive to irrigation only in 2013, a dry year when seed yield was maximized by 4.9 inches of applied water. Averaged over 6 years, seed yield of *E. heracleoides* showed a quadratic response to irrigation rate with the highest yield achieved with 5 inches of water applied.

Introduction

Native wildflower seed is needed to restore rangelands of the Intermountain West. Commercial seed production is necessary to provide the quantity of seed needed for restoration efforts. A major limitation to economically viable commercial production of native wildflower (forb) seed is stable and consistent seed productivity over years.

In native rangelands, the natural variations in spring rainfall and soil moisture result in highly unpredictable water stress at flowering, seed set, and seed development, which for other seed crops is known to compromise seed yield and quality.

Native wildflower plants are not well adapted to croplands because they often are not competitive with crop weeds in cultivated fields, which could limit wildflower seed production. Both sprinkler and furrow irrigation could provide supplemental water for seed production, but these irrigation systems risk further encouraging weeds. Also, sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. By burying drip tapes at 12-inch depth and avoiding wetting the soil surface, we designed experiments to assure flowering and seed set without undue encouragement of weeds or opportunistic diseases. The trials reported here tested the effects of three low rates of irrigation on the seed yield of *Eriogonum umbellatum* (sulphur-flower buckwheat) and *E. heracleoides* (parsnipflower buckwheat).

Materials and Methods

Plant establishment

Seed of *Eriogonum umbellatum* was received in late November in 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in the fall of 2004, but due to excessive rainfall in October, the ground preparation was not completed and planting was postponed to early 2005. To try to ensure germination, the seed was submitted to cold stratification. The seed was soaked overnight in distilled water on January 26, 2005, after which the water was drained and the seed soaked for 20 min in a 10% by volume solution of 13% bleach in distilled water. The water was drained and the seed was placed in thin layers in plastic containers. The plastic containers had lids with holes drilled in them to allow air movement. These containers were placed in a cooler set at approximately 34°F. Every few days the seed was mixed and, if necessary, distilled water added to maintain seed moisture.

In late February 2005, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between two 30-inch rows of a Nyssa silt loam with a pH of 8.3 and 1.1% organic matter. The drip tape was buried in alternating inter-row spaces (5 ft apart). The flow rate for the drip tape was 0.34 gal/min/100 ft at 8 psi with emitters spaced 16 inches apart, resulting in a water application rate of 0.066 inch/hour.

On March 3, 2005, seed of *Eriogonum umbellatum* was planted in 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted at 20-30 seeds/ft of row at 0.25-inch depth. The trial was irrigated with a minisprinkler system (R10 Turbo Rotator, Nelson Irrigation Corp., Walla Walla, WA) from March 4 to April 29 for even stand establishment. Risers were spaced 25 ft apart along the flexible polyethylene hose laterals that were spaced 30 ft apart and the water application rate was 0.10 inch/hour. A total of 1.72 inches of water was applied with the minisprinkler system. *Eriogonum umbellatum* started emerging on March 29. Starting June 24, the field was irrigated with the drip system. A total of 3.73 inches of water was applied with the drip system from June 24 to July 7. The field was not irrigated further in 2005.

Plant stands for *Eriogonum umbellatum* were uneven, and it did not flower in 2005. In early October, 2005 more seed was received from the Rocky Mountain Research Station for replanting. The empty lengths of row were replanted by hand. The seed was replanted on October 26, 2005. In the spring of 2006, the plant stands were excellent.

In early November 2009, drip tape was buried as described above in preparation for planting *Eriogonum heracleoides.* On November 25, 2009 seed of *E. heracleoides* was planted in 30-inch rows using a custom-made small-plot grain drill with disc openers. All seed was planted on the soil surface at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row at 0.26 oz/ft of row (558 lb/acre). Following planting and sawdust application, the beds were covered with row cover. The row cover (N-sulate, DeWitt Co., Inc., Sikeston, MO) covered four rows (two beds) and was applied with a mechanical plastic mulch layer. The field was irrigated for 24 hours on December 2, 2009 due to very dry soil conditions.

After *Eriogonum heracleoides* emerged, the row cover was removed in April, 2010. The irrigation treatments were not applied to *E. heracleoides* in 2010, and stands were not adequate for yield estimates. Gaps in the rows were replanted by hand on November 5, 2010. The replanted seed was covered with a thin layer of a mixture of 50% sawdust and 50% hydro-seeding mulch (Hydrostraw LLC, Manteno, IL) by volume. The mulch mixture was sprayed with water using a backpack sprayer.

Irrigation for seed production

The planted strips were divided into plots 30 ft long (*Eriogonum umbellatum* in April 2006 and *E. heracleoides* in April 2011). Each plot contained four rows of each species. The experimental designs were randomized complete blocks with four replicates. The three treatments were a nonirrigated check, 1 inch of water applied per irrigation, and 2 inches of water applied per irrigation. Each treatment received 4 irrigations that were applied approximately every 2 weeks starting at bud formation and flowering. The amount of water applied to each treatment was calculated by the length of time necessary to deliver 1 or 2 inches through the drip system. Irrigations were regulated with a controller and solenoid valves. Irrigation dates are found in Table 1.

Flowering, harvesting, and seed cleaning

Flowering dates for each species were recorded annually (Table 1). The *Eriogonum umbellatum* plots produced seed in 2006, in part because they had emerged in the spring of 2005. *Eriogonum heracleoides* started flowering in 2011. Each year, the middle two rows of each plot were harvested when seed of each species was mature (Table 1). Seed was harvested with a small-plot combine every year, except 2013 and 2016 when seed was harvested manually. *Eriogonum umbellatum* and *E. heracleoides* seeds did not separate from the flowering structures in the combine. In 2006, the unthreshed seed of *E. umbellatum* was taken to the U.S. Forest Service Lucky Peak Nursery (Boise, ID) and run through a dewinger to separate seed. The seed was further cleaned in a small clipper seed cleaner. In subsequent years, the unthreshed seed of both species was run through a meat grinder to separate the seed. The seed was further cleaned in a small clipper seed cleaner.

Cultural practices

On October 27, 2006, 50 lb phosphorus/acre and 2 lb zinc/acre were injected through the drip tape to all plots of *Eriogonum umbellatum*. On November 17, 2006, November 9, 2007, April 15, 2008, December 4, 2009, and November 17, 2010, all plots of *E. umbellatum* had Prowl® at 1 lb ai/acre broadcast on the soil surface for weed control. On March 18, 2009, Prowl at 1 lb ai/acre and Volunteer® at 8 oz/acre were broadcast on all *E. umbellatum* plots for weed control. On April 3, 2013, Select Max® at 32 oz/acre was broadcast for grass weed control on all plots of *E. umbellatum.* On November 9, 2011 and November 7, 2012, Prowl at 1 lb ai/acre was broadcast on all plots of both species. On February 26, 2014, Prowl at 1 lb ai/acre and Select Max at 32 oz/acre were broadcast on all plots of both species. On March 13, 2015, Prowl at 1 lb ai/acre was broadcast on all plots of both species. On November 11, 2015, Prowl at 1 lb ai/acre and Poast® at 30 oz/acre were broadcast on all plots of *Eriogonum umbellatum.* In addition to herbicides, hand weeding was used as necessary to control weeds.

Statistical analysis

Seed yield means were compared by analysis of variance and by linear and quadratic regression. Seed yield (y) in response to irrigation or irrigation plus precipitation (x, inches/season) was estimated by the equation $y = a + b \cdot x + c \cdot x^2$. For the quadratic equations, the amount of irrigation (x′) that resulted in maximum yield (y′) was calculated using the formula $x' = -b/2c$, where a is the intercept, b is the linear parameter, and c is the quadratic parameter. For the linear regressions, the seed yield responses to irrigation were based on the actual greatest amount of water applied plus precipitation and the measured average seed yield.

For each species, seed yields for each year were regressed separately against 1) applied water; 2) applied water plus spring precipitation; 3) applied water plus spring and winter precipitation; and 4) applied water plus spring, winter, and fall precipitation. Winter and spring precipitation occurred in the same year that yield was determined; fall precipitation occurred the prior year.

Adding the seasonal precipitation to the irrigation response equation would have the potential to provide a closer estimate of the amount of water required for maximum seed yields of the *Eriogonum* species. Regressions of seed yield each year were calculated on all the sequential seasonal amounts of precipitation and irrigation, but only some of the regressions are reported below. The period of precipitation plus applied water that had the lowest standard deviation for irrigation plus precipitation over the years was chosen as the most reliable independent variable for predicting seed yield.

Results and Discussion

Precipitation from January through June in 2009, 2012, and 2014 was close to the average of 5.8 inches (Table 2). Precipitation from January through June in 2006, 2010, and 2011 was higher than the average and precipitation from January through June in 2007, 2008, 2013, 2015, and 2016 was lower than the average of 5.8 inches. The accumulated growing degree-days (50-86°F) from January through June in 2006, 2007, and 2013-2016 were higher than average (Table 2). Both buckwheats flowered and were harvested earlier in 2013-2016 than in 2011-2012 (Table 1), consistent with more early season growing degree-days (Table 2).

Seed yields

Eriogonum umbellatum, sulfur-flower buckwheat

In 2006, seed yield of *Eriogonum umbellatum* increased with increasing water application, up to 8 inches, the highest amount tested (Tables 3 and 4). In 2007-2009, and 2012-2016 seed yield showed a quadratic response to irrigation rate. In 2010, there was no significant difference in yield between the irrigation treatments. In 2011, seed yield was highest with no irrigation. The 2010 and 2011 seasons had unusually cool and wet weather; accumulated precipitation in April through June of 2010 and 2011 was the highest over the years of the trial (Table 2). The relatively high seed yield of *E. umbellatum* in the nonirrigated treatment in 2010 and 2011 seemed to be related to the high spring precipitation. The negative effect of irrigation on seed yield in 2011 might have been compounded by the presence of rust. Irrigation could have exacerbated the rust and resulted in lower yields.

Averaged over 11 years, seed yield showed a quadratic response to irrigation rate plus spring precipitation and was estimated to be maximized at 232 lb/acre/year by applying 5.4 inches of water with average spring precipitation of 2.8 inches.

Eriogonum heracleoides, parsnipflower buckwheat

For *E. heracleoides*, there was only one year where a yield response to irrigation existed, so yield responses to only water applied are reported.

In 2013, seed yields showed a quadratic response to irrigation with a maximum seed yield at 4.9 inches of water applied. Seed yields did not respond to irrigation in 2011, 2012, 2014, 2015, and 2016 (Tables 3 and 4). Averaged over 6 years, seed yield of *E. heracleoides* showed a quadratic response to irrigation rate with the highest yield achieved with 5 inches of water applied.

Conclusions

The total irrigation requirements for these arid-land species were low and varied by species. *Eriogonum heracleoides* responded to irrigation only in 2013, a drier than average year. In the other years, natural rainfall was sufficient to maximize seed production in the absence of weed competition. Seed yield of *E. umbellatum* responded to irrigation plus spring precipitation in 10 of the 11 years, with 5-11 inches of water applied plus spring precipitation maximizing yields, depending on year. Buckwheat flowering and harvests have been earlier in 2013-2016 than in previous years, probably due to warmer weather.

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Table 1. *Eriogonum umbellatum* and *E. heracleoides* flowering, irrigation, and seed harvest dates by species in 2006-2016, Malheur Experiment Station, Oregon State University, Ontario, OR.

		Flowering dates			Irrigation dates		
Species	Year	Start	Peak	End	Start	End	Harvest
Eriogonum umbellatum	2006	19-May		20-Jul	19-May	30-Jun	3-Aug
	2007	25-May		25-Jul	2-May	24-Jun	31-Jul
	2008	5-Jun	19-Jun	20-Jul	15-May	24-Jun	24-Jul
	2009	31-May		15-Jul	19-May	24-Jun	28-Jul
	2010	4-Jun	12-19 Jun	15-Jul	28-May	8-Jul	27-Jul
	2011	8-Jun	30-Jun	20-Jul	20-May	5-Jul	1-Aug
	2012	30-May	20-Jun	4-Jul	30-May	11-Jul	24-Jul
	2013	8-May	27-May	27-Jun	8-May	19-Jun	9-Jul
	2014	20-May	4-Jun	1-Jul	13-May	24-Jun	10-Jul
	2015	13-May	26-May	25-Jun	29-Apr	10-Jun	2-Jul
	2016	16-May	26-May	25-Jun	27-Apr	7-Jun	1-Jul
Eriogonum heracleoides	2011	26-May	10-Jun	8-Jul	27-May	6-Jul	1-Aug
	2012	23-May	30-May	25-Jun	11-May	21-Jun	16-Jul
	2013	29-Apr	13-May	10-Jun	24-Apr	5-Jun	1-Jul
	2014	1-May	20-May	12-Jun	29-Apr	10-Jun	3-Jul
	2015	24-Apr	5-May	17-Jun	15-Apr	27-May	24-Jun
	2016	26-Apr	6-May	16-Jun	18-Apr	31-May	23-Jun

Table 2. Early season precipitation and growing degree-days at the Malheur Experiment Station, Ontario, OR, 2006-2016.

	Precipitation (inches)		Growing degree-days (50-86°F)
Year	Jan-Jun	Apr-Jun	Jan-Jun
2006	9	3.1	1,273
2007	3.1	1.9	1,406
2008	2.9	1.2	1,087
2009	5.8	3.9	1,207
2010	8.3	4.3	971
2011	8.3	3.9	856
2012	5.8	2.3	1,228
2013	2.6	1.4	1,319
2014	5.1	1.6	1,333
2015	4.8	2.7	1,610
2016	4.4	2.1	1,458
72-year average	5.8	2.7	1,196[a]

[a]23-year average.

Table 3. *Eriogonum umbellatum* and *E. heracleoides* seed yield in response to irrigation rate (inches/season) in 2006 through 2016. Malheur Experiment Station, Oregon State University, Ontario, OR.

		Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
		lb/acre			
Eriogonum umbellatum	2006	155.3	214.4	371.6	92.9
	2007	79.6	164.8	193.8	79.8
	2008	121.3	221.5	245.2	51.7
	2009	132.3	223	240.1	67.4
	2010	252.9	260.3	208.8	NS[a]
	2011	248.7	136.9	121	90.9
	2012	61.2	153.2	185.4	84.4
	2013	113.2	230.1	219.8	77.5
	2014	257	441.8	402.7	82.9
	2015	136.4	124.4	90.7	NS
	2016	183.4	204.3	140.8	NS
	Average	96.3	173.0	165.8	40.9
Eriogonum heracleoides	2011	55.2	71.6	49	NS[a]
	2012	252.3	316.8	266.4	NS
	2013	287.4	516.9	431.7	103.2
	2014	297.6	345.2	270.8	NS
	2015	83.6	148.2	122.3	NS
	2016	421.6	486.9	437.2	NS
	Average	211.4	311.0	279.4	72.5

[a] Not significant. There was no statistically significant trend in seed yield in response to amount of irrigation.

Table 4. Regression analysis for *Eriogonum umbellatum* and *E. heracleoides* seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + b \cdot x + c \cdot x^2$. For the quadratic equations, the amount of irrigation that resulted in maximum yield was calculated using the formula: $-b/2c$, where b is the linear parameter and c is the quadratic parameter. Malheur Experiment Station, Oregon State University, Ontario, OR.

Eriogonum umbellatum

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2006	66.6	22.9		0.52	0.05	328.0	11.4	3.4
2007	18.7	35.0	-1.8	0.69	0.05	193.8	10.0	1.9
2008	66.9	41.4	-2.4	0.73	0.01	246.6	8.7	1.4
2009	-35.6	50.6	-2.3	0.6	0.05	242.7	11.0	4.1
2010	178.5	25.2	-1.8	0.08	NS[a]	264.4	6.8	4.3
2011	308.9	-16.0		0.58	0.01	232.7	4.8	4.8
2012	-30.7	40.2	-1.9	0.65	0.01	185.4	10.7	2.6
2013	71.9	51.9	-4.0	0.62	0.05	241.3	6.5	0.9
2014	107.7	98.4	-7.0	0.76	0.01	453.7	7.0	1.7
2015	-35.7	70.4	-5.3	0.55	0.10	199.4	6.7	3.2
2016	96.3	48.9	-4.4	0.47	0.10	233.5	5.6	2.2
Average	71.0	39.1	-2.4	0.75	0.01	231.8	8.2	2.8

Eriogonum heracleoides

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2011	61.7	-0.8		0.01	NS		
2012	271.5	1.8		0.01	NS		
2013	287.4	96.7	-9.8	0.64	0.05	525.1	4.9
2014	297.6	27.2	-3.8	0.08	NS		
2015	83.6	27.5	-2.8	0.29	NS		
2016	421.6	30.7	-3.6	0.06	NS		
Average	211.4	41.3	-4.1	0.57	0.05	315.4	5.0

[a]Not significant, indicating that there was no statistically significant trend in seed yield in response to amount of irrigation in that year.