IRRIGATION REQUIREMENTS FOR NATIVE WILDFLOWER SEED PRODUCTION FOR PERENNIAL AND ANNUAL SPECIES PLANTED IN THE FALL OF 2009

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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. Native plants are often not competitive with crop weeds in cultivated fields, and this can limit wildflower seed production. Both sprinkler and furrow irrigation could provide supplemental water for seed production, but these 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 hoped 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 11 native wildflower species (Table 1) planted in 2009.

Materials and Methods

Plant Establishment

Each wildflower species was planted in 4 rows 30 inches apart (a 10-ft-wide strip) about 450 ft long on Nyssa silt loam at Malheur Experiment Station, Ontario, Oregon. The soil had a pH of 8.3 and 1.1% organic matter. In October 2012, 2 drip tapes 5 ft apart (T-Tape TSX 515-16-340) were buried at 12-inch depth to irrigate the 4 rows in the plot. Each drip tape irrigated two rows of plants. 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 November 25, 2009 seed of 9 perennial species (Table 1) was planted in 30-inch rows using a custom-made 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.

Cultural Practices in 2010

After the newly planted wildflowers had emerged, the row cover was removed in April. The irrigation treatments were not applied to these wildflowers in 2010. Stands of *Penstemon cyaneus, P. pachyphyllus,* and *Eriogonum heracleoides* were inadequate for an irrigation trial. Gaps in the rows were replanted by hand on November 5. 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.

On November 18, 2010, seed of *Cleome serrulata* was planted as described above.

Cultural Practices in 2011

Seed from the middle two rows in each plot of *Penstemon deustus* and *Eriogonum heracleoides* was harvested with a small plot combine. Seed from the middle two rows in each plot of the other species was harvested manually. On November 11, 2011, seed of *Cleome serrulata* was planted as previously described. On December 5, 2011, seed of *C. lutea* was planted as previously described. The *Cleome* species are annuals so they were replanted in new strips of land.

Cultural Practices in 2012

Many areas of the wildflower seed production study were suffering from severe iron deficiency early in the spring of 2012. On April 13, 2012, 50 lb nitrogen/acre, 10 lb phosphorus/acre, and 5 lb iron (Fe)/acre was applied to all plots of *Lomatium nudicaule, Cymopterus bipinnatus, Penstemon deustus, P. cyaneus,* and *P. pachyphyllus* as liquid fertilizer injected through the drip tape. On April 23, 2012, 5 lb Fe/acre was applied to all plots of *P. deustus, P. cyaneus, P. pachyphyllus, Eriogonum heracleoides, Dalea searlsiae, D. ornata,* and *Astragalus filipes* as liquid fertilizer injected through the drip tape.

Flea beetles were observed feeding on leaves of *Cleome serrulata* and *C. lutea* in April. On April 29, all plots of *C. serrulata* and *C. lutea* were sprayed with Capture® at 5 oz/acre to control flea beetles. On June 11, *C. serrulata* was again sprayed with Capture at 5 oz/acre to control a reinfestation of flea beetles.

Many plants died in the *Penstemon deustus* plots during the winter and spring of 2011-2012. For *P. deustus*, only the undamaged parts in each plot were harvested. Seed of all species was harvested and cleaned manually. On October 26, dead *P. deustus* plants were removed and the empty row lengths were replanted by hand at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row. Following planting and sawdust application, the beds were covered with row cover.

On November 1, seed of *Cleome serrulata* and *C. lutea* 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. Following planting and sawdust application, the beds were covered with row cover.

Cultural Practices in 2013

On March 27, row cover was removed and bird netting placed over the *Cleome serrulata* and *C. lutea* plots to protect seedlings from bird feeding. The bird netting was placed over No. 9 galvanized wire hoops. Bird netting was also placed over *Cymopterus bipinnatus* on March 29 to protect new shoots.

Table 1. Wildflower species planted in the fall of 2009 at the Malheur Experiment Station, Oregon State University, Ontario, OR. All species are perennial except *Cleome serrulata* and *Cleome lutea*.

Species	Common names	Growth habit
Penstemon deustus	Scabland penstemon, hotrock penstemon	Perennial
Penstemon cyaneus	Blue penstemon	Perennial
Penstemon pachyphyllus	Thickleaf beardtongue	Perennial
Eriogonum heracleoides	Parsnipflower buckwheat	Perennial
Dalea searlsiae	Searls' prairie clover	Perennial
Dalea ornata	Western prairie clover, Blue Mountain prairie clover	Perennial
Astragalus filipes	Basalt milkvetch	Perennial
Cleome serrulata	Rocky Mountain beeplant	Annual
Cleome lutea	Yellow beeplant	Annual
Lomatium nudicaule	Barestem biscuitroot, Barestem lomatium	Perennial
Cymopterus bipinnatus[a]	Hayden's cymopterus	Perennial

[a] recently classified as *Cymopterus nivalis* S. Watson "snowline springparsley."

Irrigation for Seed Production

In April, 2011, each strip of each wildflower species was divided into 12 30-ft plots. Each plot contained four rows of each species. The experimental design for each species was a randomized complete block 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 with flowering of the wildflowers. 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. After each irrigation, the amount of water applied was read on a water meter and recorded to ensure correct water applications.

The drip-irrigation system was designed to allow separate irrigation of the species due to different timings of flowering and seed formation. The three *Penstemon* spp. were irrigated together and the two *Dalea* spp. were irrigated together. *Eriogonum heracleoides* and *Astragalus filipes* were irrigated individually. Flowering, irrigation, and harvest dates were recorded (Table 2). *Lomatium nudicaule* flowered in 2012; irrigation treatments were applied and seed was harvested. *Cymopterus bipinnatus* had not flowered as of 2012, but differential irrigation treatments were applied starting in 2012.

Soil volumetric water content was measured by neutron probe. The neutron probe was calibrated by taking soil samples and probe readings at 8-, 20-, and 32-inch depths during installation of the access tubes. The soil water content was determined volumetrically from the soil samples and regressed against the neutron probe readings for each soil depth. Regression equations were then used to transform the neutron probe readings during the season into volumetric soil water content.

Table 2. Native wildflower flowering, irrigation, and seed harvest dates by species. Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Flowering			Irrigation		Harvest
	start	peak	end	start	end	
	2011					
Penstemon cyaneus	23-May	15-Jun	8-Jul	13-May	23-Jun	18-Jul
Penstemon pachyphyllus	10-May	30-May	20-Jun	13-May	23-Jun	15-Jul
Penstemon deustus	23-May	20-Jun	14-Jul	13-May	23-Jun	16-Aug
Eriogonum heracleoides	26-May	10-Jun	8-Jul	27-May	6-Jul	1-Aug
Dalea searlsiae	8-Jun	20-Jun	20-Jul	27-May	6-Jul	21-Jul
Dalea ornata	8-Jun	20-Jun	20-Jul	27-May	6-Jul	22-Jul
Astragalus filipes	20-May	26-May	30-Jun	13-May	23-Jun	18-Jul
Cleome serrulata	25-Jun	30-Jul	15-Aug	21-Jun	2-Aug	26-Sep
Lomatium nudicaule		No flowering				
Cymopterus bipinnatus		No flowering				
	2012					
Penstemon cyaneus	16-May	30-May	10-Jun	27-Apr	7-Jun	27-Jun
Penstemon pachyphyllus	23-Apr	2-May	10-Jun	27-Apr	7-Jun	26-Jun
Penstemon deustus	16-May	30-May	4-Jul	27-Apr	7-Jun	7-Aug
Eriogonum heracleoides	23-May	30-May	25-Jun	11-May	21-Jun	16-Jul
Dalea searlsiae	23-May	10-Jun	30-Jun	11-May	21-Jun	10-Jul
Dalea ornata	23-May	10-Jun	30-Jun	11-May	21-Jun	11-Jul
Astragalus filipes	28-Apr	23-May	19-Jun	11-May	21-Jun	5-Jul
Cleome serrulata	12-Jun	30-Jun	30-Jul	13-Jun	25-Jul	24-Jul to 30-Aug
Cleome lutea	16-May	15-Jun	30-Jul	2-May	13-Jun	12-Jul to 30-Aug
Lomatium nudicaule	12-Apr	1-May	30-May	18-Apr	30-May	22-Jun
Cymopterus bipinnatus		No flowering				
	2013					
Penstemon cyaneus	3-May	21-May	5-Jun	24-Apr	5-Jun	11-Jul
Penstemon pachyphyllus	26-Apr		21-May	24-Apr	5-Jun	8-Jul
Penstemon deustus	3-May	18-May	15-Jun	24-Apr	5-Jun	
Eriogonum heracleoides	29-Apr	13-May	10-Jun	24-Apr	5-Jun	1-Jul
Dalea searlsiae	13-May		15-Jun	8-May	19-Jun	29-Jun
Dalea ornata	13-May	21-May	15-Jun	8-May	19-Jun	28-Jun
Astragalus filipes	3-May	10-May	25-May	8-May	19-Jun	28-Jun
Lomatium nudicaule	11-Apr		20-May	12-Apr	22-May	10-Jun
Cymopterus bipinnatus	5-Apr		15-May	12-Apr	22-May	10-Jun

Results and Discussion

Precipitation from January through July was higher than average in 2011, close to average in 2012, and lower than average in 2013 (Fig. 1). The accumulation of growing degree-days (50-86°F) was below average in 2011, close to average in 2012, and higher than average in 2013 (Fig. 2).

Flea beetle feeding occurred earlier in 2013 than in 2012. Upon removal of the row cover in March the flea beetle damage to the seedlings of *Cleome serrulata* and *C. lutea* was extensive and resulted in full stand loss. Harvested seed pods of *Dalea ornata, D. searlsiae*, and *Astragalus filipes* had extensive damage from feeding by seed beetles in 2013, indicating that control measures during and following flowering will be necessary to maintain seed yields.

Penstemon cyaneus

Seed yields did not respond to irrigation in 2011 (Tables 3 and 4). In 2012, seed yields increased with increasing irrigation up to the highest tested of 8 inches. In 2013, seed yields showed a quadratic response to irrigation with a maximum seed yield at 4 inches of water applied.

Penstemon pachyphyllus

Seed yields did not respond to irrigation in 2011 and 2012. In 2013, seed yields increased with increasing irrigation up to the highest tested of 8 inches.

Eriogonum heracleoides

Seed yields did not respond to irrigation in 2011 and 2012. In 2013, seed yields showed a quadratic response to irrigation with a maximum seed yield at 4.9 inches of water applied.

Dalea searlsiae

In 2011, seed yields were highest with no irrigation. In 2012, seed yields showed a quadratic response to irrigation with a maximum seed yield at 6.6 inches of water applied. In 2013, seed yields increased with increasing irrigation rate up to the highest tested of 8 inches.

Dalea ornata

Seed yields did not respond to irrigation in 2011. Seed yields showed a quadratic response to irrigation in 2012 and 2013, with a maximum seed yield at 7.7 and 8.1 inches of water applied, respectively. Averaged over the 3 years, seed yield increased with increasing irrigation rate up to the highest tested of 8 inches.

Astragalus filipes

Seed yields did not respond to irrigation in any year from 2011 through 2013.

Lomatium nudicaule

Seed yields did not respond to irrigation in either 2012 or 2013.

Cymopterus bipinnatus

Seed yields did not respond to irrigation in 2013.

Cleome serrulata

In 2011, seed yields increased with increasing irrigation up to the highest tested of 8 inches. Seed yields did not respond to irrigation in 2012. Averaged over the 2 years, seed yield increased with increasing irrigation rate up to the highest tested of 8 inches. There was no plant stand in 2013.

Cleome lutea

Seed yields did not respond to irrigation in 2012. There was no plant stand in 2013. Early attention to flea beetle control is essential for *Cleome* seed production.

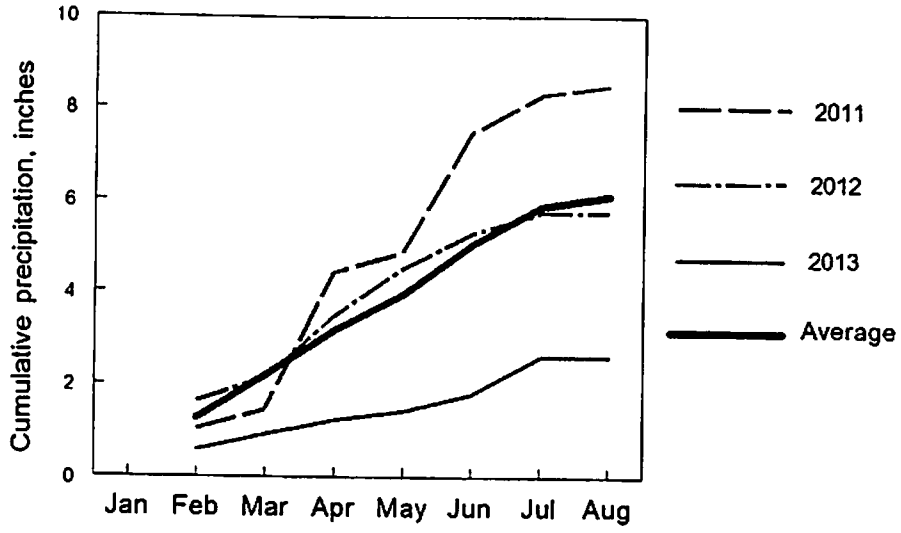

Figure 1. Cumulative annual and 66-year-average precipitation from January through July at the Malheur Experiment Station, Oregon State University, Ontario, OR.

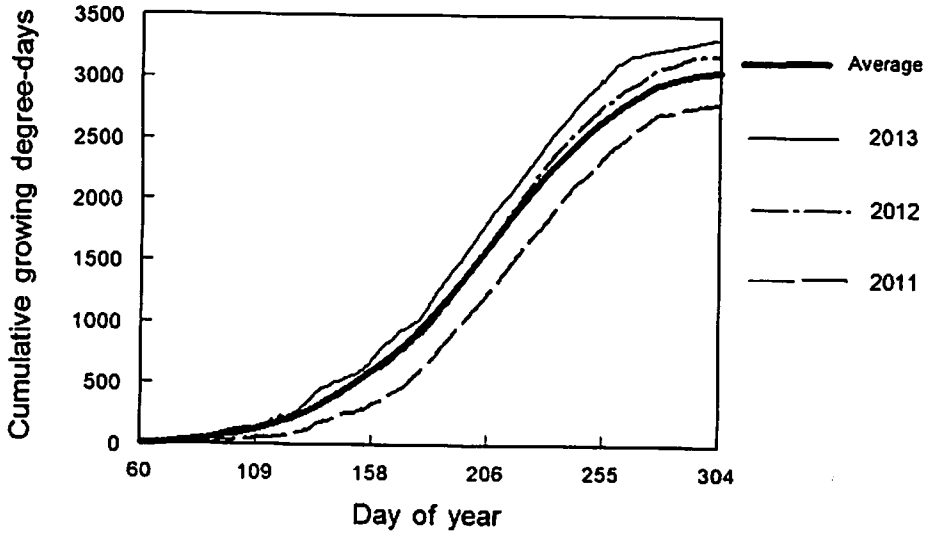

Figure 2. Cumulative growing degree-days (50-86°F) for selected years and 23-year average at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 3. Native wildflower seed yield response to irrigation rate (inches/season). Malheur Experiment Station, Oregon State University, Ontario, OR.

	2011				2012			
Species	0 inches	4 inches	8 inches	LSD (0.05)	0 inches	4 inches	8 inches	LSD (0.05)
	lb/acre				lb/acre			
Penstemon cyaneus	857.2	821.4	909.4	NS[a]	343.3	474.6	581.2	202.6[b]
Penstemon pachyphyllus	569.9	337.6	482.2	NS	280.5	215.0	253.7	NS
Penstemon deustus	637.6	477.8	452.6	NS	308.7	291.8	299.7	NS
Eriogonum heracleoides	55.2	71.6	49.0	NS	252.3	316.8	266.4	NS
Dalea searlsiae	262.7	231.2	196.3	50.1	175.5	288.8	303.0	93.6
Dalea ornata	451.9	410.8	351.7	NS	145.1	365.1	431.4	189.3
Astragalus filipes	87.0	98.4	74.0	NS	22.7	12.6	16.1	NS
Lomatium nudicaule					53.8	123.8	61.1	NS
Cymopterus bipinnatus								
Cleome serrulata	446.5	499.3	593.6	100.9[b]	184.3	162.9	194.7	NS
Cleome lutea					111.7	83.7	111.4	NS

	2013				Average			
Species	0 inches	4 inches	8 inches	LSD (0.05)	0 inches	4 inches	8 inches	LSD (0.05)
	lb/acre				lb/acre			
Penstemon cyaneus	221.7	399.4	229.2	74.4	474.1	565.1	573.2	NS
Penstemon pachyphyllus	159.4	196.8	249.7	83.6	336.6	249.8	328.5	NS
Penstemon deustus					512.7[c]	403.1[c]	374.2[c]	NS
Eriogonum heracleoides	287.4	516.9	431.7	103.2	198.3	301.7	249.0	NS
Dalea searlsiae	14.8	31.7	44.4	6.1	151.0	183.9	181.2	NS
Dalea ornata	28.6	104.6	130.4	38.8	208.5	293.5	304.5	64.2[b]
Astragalus filipes	8.5	9.8	6.1	2.7	39.4	24.0	32.1	NS
Lomatium nudicaule	357.6	499.1	544.0	NS	205.7[c]	311.5[c]	302.6[c]	NS
Cymopterus bipinnatus	194.2	274.5	350.6	NS	194.2[d]	274.5[d]	350.6[d]	NS
Cleome serrulata					315.4[c]	331.1[c]	349.2[c]	NS
Cleome lutea					111.7[d]	83.7[d]	111.4[d]	NS

[a] not significant, [b] LSD (0.10), [c] 2-year average, [d] only one year of data.

Table 4. Regression parameters for native wildflower seed yield in response to irrigation rate (inches/season). 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. Continued on the next page.

Penstemon cyaneus

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2011	836.6	6.5		0.01	NS		
2012	855.8	29.7		0.84	0.001	1093.6	8.0
2013	221.7	87.9	-10.9	0.63	0.05	399.4	4.0
Average	487.9	12.4		0.14	NS		

Penstemon pachyphyllus

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2011	507.1	-11.0		0.04	NS		
2012	263.1	-3.3		0.01	NS		
2013	156.8	11.3		0.33	0.10	247.2	8.0
Average	309.0	-1.0		0.01	NS		

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
Average	224.3	6.3		0.12	NS		

Dalea searlsiae

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2011	263.3	-8.3		0.49	0.05	263.3	0
2012	175.5	40.7	-3.1	0.62	0.05	309.3	6.6
2013	15.5	3.7		0.54	0.01	45.1	8
Average	156.9	3.8		0.22	NS		

Dalea ornata

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
2011	454.9	-12.5		0.11	NS		
2012	145.1	74.2	-4.8	0.65	0.01	431.8	7.7
2013	28.6	25.3	-1.6	0.88	0.001	130.4	8.1
Average	220.9	12.0		0.37	0.05	316.8	8

[a]Not significant. There was no statistically significant difference in yield between the nonirrigated plots and the plots receiving 4 or 8 inches of water.
[b]No response.

Table 4. Continued. Regression parameters for native wildflower seed yield in response to irrigation rate (inches/season). Malheur Experiment Station, Oregon State University, Ontario, OR.

Astragalus filipes Year	intercept	linear	quadratic	R^2	*P*	Estimated maximum yield	Water applied for estimated maximum yield
						lb/acre	inches/season
2011	90.6	-1.6		0.01	NS[a]	90.6	0
2012	19.7	-0.8		0.04	NS	19.7	0
2013	9.3	-0.3		0.1	NS	9.3	0
Average	35.5	-0.9		0.02	NS	39.9	0

Lomatium nudicaule Year	intercept	linear	quadratic	R^2	*P*	Estimated maximum yield	Water applied for estimated maximum yield
						lb/acre	inches/season
2012	75.9	0.9		0.01	NS	No resp.[b]	
2013	373.7	23.3		0.1	NS	No resp.[b]	
Average	224.8	12.1		0.07	NS		

Cymopterus bipinnatus Year	intercept	linear	quadratic	R^2	*P*	Estimated maximum yield	Water applied for estimated maximum yield
						lb/acre	inches/season
2013	194.9	19.6		0.07	NS	No resp.[b]	

Cleome serrulata Year	intercept	linear	quadratic	R^2	*P*	Estimated maximum yield	Water applied for estimated maximum yield
						lb/acre	inches/season
2011	439.6	18.4		0.35	0.05	586.7	8
2012	175.4	1.3		0.01	NS	No resp.[b]	
Average	307.5	9.8		0.33	0.05	386.3	8

Cleome lutea Year	intercept	linear	quadratic	R^2	*P*	Estimated maximum yield	Water applied for estimated maximum yield
						lb/acre	inches/season
2012	102.4	-0.031		0.01	NS	102.4	0

[a]Not significant. There was no statistically significant difference in yield between the nonirrigated plots and the plots receiving 4 or 8 inches of water.
[b]No response.