IRRIGATION REQUIREMENTS FOR SEED PRODUCTION OF SEVERAL NATIVE WILDFLOWER SPECIES PLANTED IN THE FALL OF 2012

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Introduction

Commercial seed production of native wildflowers is necessary to provide the quantity of seed needed for restoration of Intermountain West rangelands. Native wildflower plants may not be well adapted to croplands. Native plants are often not competitive with crop weeds in cultivated fields, and this poor competitiveness with weeds 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 tape at a 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 effects of three low rates of irrigation on seed yield of 13 native wildflower species (Table 1).

Table 1. Wildflower species planted in the fall of 2012 at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common name	Longevity	Row spacing (inches)
Chaenactis douglasii	Douglas' dustymaiden	perennial	30
Crepis intermedia[a]	Limestone hawksbeard	perennial	30
Cymopterus bipinnatus[b]	Hayden's cymopterus	perennial	30
Enceliopsis nudicaulis	nakedstem sunray	perennial	30
Heliomeris multiflora	showy goldeneye	perennial	30
Ipomopsis aggregata	scarlet gilia	biennial	15
Ligusticum canbyi	Canby's licorice-root	perennial	30
Ligusticum porteri	Porter's licorice-root	perennial	30
Machaeranthera canescens	hoary tansyaster	perennial	30
Nicotiana attenuata	coyote tobacco	perennial	30
Phacelia linearis	threadleaf phacelia	annual	15
Phacelia hastata	silverleaf phacelia	perennial	15
Thelypodium milleflorum	manyflower thelypody	biennial	30

[a]Planted in the fall of 2011.
[b]Recently classified as *Cymopterus nivalis* S. Watson “snowline springparsley”. Planted in the fall of 2009.

Materials and Methods

Plant establishment

Each wildflower species was planted on 60-inch beds in rows 450 ft long on Nyssa silt loam at the Malheur Experiment Station, Ontario, Oregon. The soil had a pH of 8.3 and 1.1% organic matter. In October 2012, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth in the center of each bed to irrigate the rows in the plot. 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 October 30, 2012 seed of 11 species (Table 1) was planted in either 15-inch or 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 (N-sulate, DeWitt Co., Inc., Sikeston, MO), which covered four rows (two beds) and was applied with a mechanical plastic mulch layer. *Cymopterus bipinnatus* was planted on November 25, 2009, and *Crepis intermedia* was planted on November 28, 2011 as previously described using similar methods.

Weeds were controlled by hand-weeding as necessary.

Starting in March following fall planting, the row cover was removed. Immediately following the removal of the row cover, bird netting was placed over the seedlings on No. 9 galvanized wire hoops to prevent bird feeding on young seedlings and new shoots. During seedling emergence, wild bird seed was placed several hundred feet from the trial to attract quail away from the trials. Bird netting was removed in early May. Bird netting was applied and removed each spring.

Cultural practices for *Cymopterus bipinnatus* and *Crepis intermedia*

On April 13, 2012, 50 lb nitrogen/acre, 10 lb phosphorus/acre, and 0.3 lb iron/acre was applied to all plots of *Cymopterus bipinnatus* as liquid fertilizer injected through the drip tape.

Cultural practices in 2013

On July 26, all plots of *Machaeranthera canescens* were sprayed with Capture® at 19 oz/acre (0.3 lb ai/acre) for aphid control. On October 31, seed of *Phacelia linearis* was planted as previously described.

Due to poor stand, seed of *Chaenactis douglasii* was replanted on November 1, as previously described. Stand of *Nicotiana attenuata* was extremely poor and seed was unavailable for replanting.

Cultural practices in 2014

Stand of *Chaenactis douglasii*, which was replanted in the fall of 2013, was poor and did not allow evaluation of irrigation responses.

On November 11, *Phacelia linearis, Nicotiana attenuata,* and *Thelypodium milleflorum* were replanted as previously described. Lengths of row with missing stand in plots of *Chaenactis douglasii* were replanted by hand and row cover was not applied to the replanting.

Cultural practices in 2015

On November 2, *Nicotiana attenuata* and *Enceliopsis nudicaulis* were replanted as previously described. Before planting, the ground was not tilled, only cultipacked. On November 5, *Phacelia linearis, Chaenactis douglasii,* and *Ipomopsis aggregata* were replanted as previously described.

Irrigation for seed production

In March of 2010 for *Cymopterus bipinnatus,* and March of 2013 for the other species, the planted strip of each wildflower species was divided into 12 30-ft-long 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 per irrigation, and 2 inches of water per irrigation. Each treatment received four 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.

The drip-irrigation system was designed to allow separate irrigation of each species due to different timings of flowering and seed formation. All species were irrigated separately except the two *Phacelia* spp. and the two *Ligusticum* spp. Flowering, irrigation, and harvest dates were recorded (Table 2) with the exception of *Nicotiana attenuata*, which did not germinate in 2014 and the *Ligusticum* spp., which did not flower.

Harvest

All species were harvested manually in 2013. Due to a long flowering duration, seed of *Enceliopsis nudicaulis, Chaenactis douglasii,* and *Crepis intermedia* required multiple harvests. Seed of *Enceliopsis nudicaulis* was harvested manually once a week. Seed of *Chaenactis douglasii* and *Crepis intermedia* was harvested weekly with a leaf blower in vacuum mode. In 2016, the duration of flowering for *C. intermedia* was much shorter and uniform in timing between irrigation treatments. In 2016, seed of *C. intermedia* was harvested by mowing and bagging just prior to the seed heads opening. A seed sample from each plot of *C. intermedia* was cleaned manually to determine the proportion of pure seed. A sample of light yellow (immature) seed and dark brown (mature) seed of *C. intermedia* was analyzed for viability (tetrazolium). In 2016, seed of *Chaenactis douglasii* was harvested manually once a week.

Machaeranthera canescens seed was harvested by cutting and windrowing the plants. After drying for 2 days the *M. canescens* plants were beaten on plastic tubs to separate the seed heads from the stalks. *Phacelia hastata* was harvested with a small-plot combine in 2014 and 2015. *Heliomeris multiflora* was harvested with a small plot combine in 2015 and 2016. The duration of flowering for *H. multiflora* tends to increase with increasing irrigation. In 2013 and 2014, the duration of flowering in the wetter plots of *H. multiflora* was much longer than in the drier plots, making a single mechanical harvest unfeasible. In 2015, the duration of flowering in the wetter plots of *Heliomeris multiflora* was shorter, enabling mechanical harvest. In 2016, plots of the driest treatment were harvested manually before the other plots, which were harvested mechanically on July 8.

Seed of all species was cleaned manually.

Results and Discussion

Precipitation from January through June in 2013 (2.6 inches) was lower and in 2011 (8.3 inches) was higher than the 73-year average of 5.8 inches (Table 3). Precipitation in the other years was close to the average. The accumulation of growing degree-days (50-86°F) was higher than average in 2013-2016 (Table 3).

Stands of *Ligusticum porteri* and *L. canbyi* were poor and uneven and did not permit evaluation of irrigation responses. Stands of *Chaenactis douglasii* were poor in 2013 and 2014, and did not permit evaluation of irrigation responses. After replanting in the fall of 2013 and 2014, adequate stand of *C. douglasii* was established, allowing evaluations of irrigation responses in 2015 and 2016.

Stand of *Nicotiana attenuata* was uneven and did not permit evaluation of irrigation responses in 2015.

Ipomopsis aggregata flowered very little in 2013, then flowered and set seed in 2014. The stand of *I. aggregata* died over the winter of 2014-2015, which indicated a biennial growth habit. *Cymopterus bipinnatus* did not flower in either 2010 or 2011, and flowered very little in 2012.

Stand of replanted *Phacelia linearis* was very poor in 2015, but was replaced by an excellent volunteer stand of *Phacelia hastata*, originating from unharvested seed of the adjacent *P. hastata* stand. Irrigation responses for *P. hastata* were evaluated for the new stand and for the 3-year-old stand. The original stand of *P. hastata*, planted in the fall of 2012, was extremely poor in 2016 and seed was not harvested. *Phacelia linearis* was replanted in the fall of 2016 in a different location in the field, but stand in the spring of 2016 was extremely poor.

Crepis intermedia flowered and produced seed for the first time in 2015, the third year after fall planting in 2011. The uniform and short flowering of *C. intermedia* in 2016 allowed the seed from all plots to be harvested once. A single mechanical harvest is more efficient, but some of the seed could be immature because harvest needed to occur just before seed heads opened. In 2016, 77% of the seed harvested was mature and had a viability of 57%. The other 23% of the harvested seed was immature and had a viability of 5%. This suggests that the single harvest as conducted in this trial resulted in adequate seed quality.

Extensive die-off of *Enceliopsis nudicaulis* occurred over the winter of 2014-2015, and was more severe in the plots receiving the highest amount of irrigation.

Partial die-off of *Machaeranthera canescens* over the winter of 2015-2016 resulted in stand too uneven for an irrigation trial in 2016.

Seed yield responses (Tables 4 and 5)

Chaenactis douglasii seed yields did not respond to irrigation in 2015 and 2016.

Crepis intermedia seed yields increased with increasing irrigation rate up to the highest rate of 8 inches in 2015. In 2016, seed yields of *C. intermedia* did not respond to irrigation.

Cymopterus bipinnatus seed yields did not respond to irrigation in 2013 and 2016. In 2014, seed yields increased with increasing irrigation rate up to the highest rate of 8 inches. In 2015, seed yields showed a quadratic response to irrigation with a maximum seed yield at 4.2 inches of water applied.

Enceliopsis nudicaulis seed yield was very low and did not respond to irrigation in 2013. In 2014, seed yield showed a quadratic response to irrigation with a maximum seed yield at 5.4 inches of water applied. Significant stand loss occurred over the winter of 2014-2015, especially in the irrigated plots. Seed yields of *E. nudicaulis* were substantially reduced in 2015 and were highest without irrigation. In 2016, seed yield showed a quadratic response to irrigation with a maximum seed yield at 5.8 inches of water applied. Seed yields have been very low each year due at least in part to very low plant stands.

Heliomeris multiflora seed yield increased with increasing irrigation rate up to the highest rate of 8 inches in 2013-2015; *H. multiflora* seed yield did not respond to irrigation in 2016.

Ipomopsis aggregata seed yields were highest with 4 inches of water applied in 2014.

Machaeranthera canescens seed yields showed a quadratic response to irrigation with a maximum seed yield at 2.4 inches of water applied in 2013. In 2014, 2015, and averaged over the 3 years, seed yields of *M. canescens* did not respond to irrigation.

Phacelia hastata (planted in the fall of 2012) seed yields showed a quadratic response to irrigation with a maximum seed yield at 5.4 and 7.5 inches of water applied in 2013 and 2014, respectively. In 2015, seed yield of *P. hastata* did not respond to irrigation, possibly due to loss of stand in this weak perennial.

Seed yields of *P. hastata* (planted in the fall of 2014) increased with increasing irrigation rate up to the highest rate of 8 inches in 2015. In 2016, seed yields of *P. hastata,* showed a quadratic response to irrigation with a maximum seed yield at 4 inches of water applied. Averaged over the two years, seed yields of *P. hastata,* showed a quadratic response to irrigation with a maximum seed yield at 5.3 inches of water applied.

Seed yields of *Phacelia linearis* showed a quadratic response to irrigation in 2013 with a maximum seed yield at 6.2 inches of water applied. In 2014, seed yields of *P. linearis* did not respond to irrigation.

Seed yield of *Thelypodium milleflorum* did not respond to irrigation in 2014 or 2016.

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

	Flowering dates			Irrigation dates		
Year	Start	Peak	End	Start	End	Harvest
***Chaenactis douglasii*, Douglas' dustymaiden**						
2013	23-May	30-Jun	15-Jul	22-May	3-Jul	2-Jul, 22-Jul
2014	20-May		15-Jul	13-May	24-Jun	poor stand
2015	5-May		10-Jul	5-May	17-Jun	weekly, 6-8 to 7-15
2016	23-May			23-May	8-Jul	weekly, 6-17 to
***Machaeranthera canescens*, hoary tansyaster**						
2013	13-Aug		1-Oct	17-Jul	28-Aug	2-Oct
2014	20-Aug	17-Sep	5-Oct	22-Jul	2-Sep	6-Oct
2015	10-Aug	17-Sep	1-Oct	11-Aug	22-Sep	6-Oct, 15-Oct
2016	17-Aug	20-Sep	10-Oct			partial winter die-off
***Phacelia hastata*, silverleaf phacelia**						
2013	17-May		30-Jul	22-May	3-Jul	30-Jul (0 in), 7-Aug, 19-Aug (8 in)
2014	5-May		10-Jul	29-Apr	10-Jun	14-Jul
2015 (1st year)	28-Apr	26-May	7-Aug	20-May	30-Jun	6-Aug
2015 (3rd year)	28-Apr	26-May	7-Aug	29-Apr	10-Jun	7-Jul (0 in), 21-Jul (4, 8 in)
2016	28-Apr		17-Jun	27-Apr	7-Jun	
***Phacelia linearis*, threadleaf phacelia**						
2013	3-May	16-May	15-Jun	2-May	12-Jun	2-Jul
2014	5-May	4-Jun	1-Jul	1-May	10-Jun	7-Jul
2015		winter die-off				
***Enceliopsis nudicaulis*, nakedstem sunray**						
2013	30-Jun		15-Sep	3-Jul	14-Aug	weekly, 8-Aug to 30-Aug
2014	5-May	1-Jul	30-Jul	6-May	17-Jun	weekly, 14-Jul to 30-Aug
2015	28-Apr	13-May	5-Aug	29-Apr	10-Jun	weekly, 2-Jun to 15-Aug
2016	20-Apr		30-Jul	3-May	14-Jun	weekly, 27-Apr to 29-Jul
***Heliomeris multiflora*, showy goldeneye**						
2013	15-Jul		30-Aug	5-Jun	17-Jun	8-Aug, 15-Aug, 28-Aug
2014	20-May	20-Jun	30-Aug	13-May	24-Jun	weekly, 15-Jul to 15-Aug
2015	5-May	26-May	10-Jul	5-May	17-Jun	13-Jul
2016	5-May	15-Jun	30-Sep	9-May	22-Jun	8-Jul

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

	Flowering dates			Irrigation dates		
Year	Start	Peak	End	Start	End	Harvest
***Cymopterus bipinnatus,* Hayden's cymopterus**						
2013	5-Apr		15-May	12-Apr	22-May	10-Jun
2014	7-Apr		29-Apr	7-Apr	20-May	16-Jun
2015	25-Mar		24-Apr	1-Apr	13-May	8-Jun
2016	15-Mar		25-Apr	31-Mar	9-May	7-Jun
***Ipomopsis aggregata,* scarlet gilia**						
2013	31-Jul	very little flowering		31-Jul	11-Sep	
2014	22-Apr	13-May	30-Jul	23-Apr	3-Jun	20-Jun
2015		winter die-off				
2016	no flowering			7-Jun	22-Jul	
***Thelypodium milleflorum,* manyflower thelypody**						
2013		No flowering				
2014	22-Apr	5-May	10-Jun	23-Apr	3-Jun	2-Jul
2015		No flowering				
2016	11-Apr	6-May	8-Jun	11-Apr	23-May	21-Jun
***Crepis intermedia,* limestone hawksbeard**						
2015	28-Apr	5-May	1-Jun	21-Apr	3-Jun	weekly, 6-1 to 7-2
2016	29-Apr		25-May	27-Apr	7-Jun	26-May
***Nicotiana attenuata*, coyote tobacco**						
2016	16-May		31-Jul	16-May	22-Jun	weekly, 21-Jun to 29-Jul

Table 3. Early season precipitation and growing degree-days at the Malheur Experiment Station, Ontario, OR, 2013-2016.

	Precipitation (inches)		Growing degree-days (50-86°F)
Year	Jan-Jun	Apr-Jun	Jan-Jun
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
73-year average	5.8	2.6	1,196[a]

[a]23-year average.

Table 4. Native wildflower seed yield (lb/acre) in response to season-long irrigation rate (inches). Malheur Experiment Station, Oregon State University, Ontario, OR.

		Irrigation rate			
Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
Chaenactis douglasii	2015	132.1	137.6	183.3	NS[a]
	2016	29.1	16.0	27.2	NS
	Average	80.6	76.8	105.2	NS
Crepis intermedia	2015	75.5	75.8	153.7	58.1
	2016	91.9	113.1	85.6	NS
	Average	83.7	94.5	118.9	NS
Cymopterus bipinnatus	2013	194.2	274.5	350.6	NS
	2014	1236.2	1934	2768.5	844.7
	2015	312.3	749.0	374.9	240.7
	2016	1501.4	2120.6	1799.0	546.6 [b]
	Average	811.0	1339.0	1216.1	282.2
Enceliopsis nudicaulis	2013	2.3	6.8	5.9	NS
	2014	1.5	34.6	29.1	20.7
	2015	15.7	3.2	4.4	7.3
	2016	10.5	47.6	45.9	34.9
	Average	7.5	25.3	21.3	16.8
Heliomeris multiflora	2013	28.7	57.6	96.9	NS
	2014	154.6	200.9	271.7	107.3[b]
	2015	81.7	115.6	188.2	58.2
	2016	92.3	89.2	98.0	NS
	Average	89.3	114.1	163.7	33.0
Ipomopsis aggregata	2014	47.1	60.9	63.6	9
Machaeranthera canescens	2013	206.1	215	124.3	73.6
	2014	946.1	1210.2	1026.3	NS
	2015	304.1	402.6	459.1	NS
	Average	163.0	240.3	233.3	NS
Nicotiana attenuata	2016	49.4	151.0	95.8	81.4
Phacelia hastata	2013	35.3	102.7	91.2	35.7
(planted fall 2012)	2014	87.7	305.7	366.4	130.3
	2015	78.8	79.3	65.0	NS
	Average	67.3	162.6	174.2	34.5
Phacelia hastata	2015	0.0	21.4	50.4	13.7
(planted fall 2014)	2016	82.5	125.2	83.1	26.8
	Average	41.2	73.3	66.7	17.2
Phacelia linearis	2013	121.4	306.2	314.2	96
	2014	131.9	172.9	127.2	NS
	Average	126.7	239.5	220.7	87.2
Thelypodium milleflorum	2014	200.5	246.2	205.6	NS
	2016	121.9	110.0	63.3	NS
	Average	171.7	224.6	152.6	NS

[a]Not significant.
[b]LSD (0.10).

Table 5. Regression analysis for native wildflower seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + bx + cx^2$. 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.

Species	Year	intercept	linear	quadratic	R^2	P	Maximum yield	Water applied for maximum yield
							lb/acre	inches/season
Chaenactis douglasii	2015	125.4	6.4		0.08	NS[a]		
	2016	25.1	-0.2		0.01	NS		
	Average	75.2	3.1		0.07	NS		
Crepis intermedia	2015	58.6	12.7		0.32	0.10	160	8.0
	2016	91.9	11.4	-1.5	0.25	NS		
	Average	81.4	4.4		0.13	NS		
Cymopterus bipinnatus	2013	194.9	19.6		0.07	NS		
	2014	1214.6	190.6		0.41	0.05	2740	8
	2015	312.3	210.5	-25.3	0.46	0.10	750	4.2
	2016	1501.4	272.4	-29.4	0.34	NS	2132	4.6
	Average	811.0	213.4	-20.3	0.51	0.05	1371	5.2
Enceliopsis nudicaulis	2013	3.1	0.4		0.16	NS		
	2014	1.5	13.1	-1.2	0.6	0.05	37	5.4
	2015	13.4	-1.4		0.29	0.10	13	0.0
	2016	10.5	14.1	-1.2	0.57	0.05	51.6	5.8
	Average	7.5	7.2	-0.7	0.46	0.10	26.4	5.3
Heliomeris multiflora	2013	27	8.5		0.38	0.05	95	8
	2014	150.5	14.6		0.27	0.10	268	8
	2015	75.2	13.3		0.48	0.05	182	8
	2016	90.7	0.7		0.01	NS		
	Average	85.2	9.3		0.50	0.01	160	9
Ipomopsis aggregata	2014	48.5	2.1		0.23	NS		
Machaeranthera canescens	2013	206.1	14.7	-3.1	0.54	0.05	223	2.4
	2014	946.1	122	-14	0.13	NS		
	2015	311.1	19.4		0.02	NS		
	Average	163.0	29.9	-2.6	0.03	NS		
Nicotiana attenuata	2016	49.4	45.0	-4.9	0.50	0.05	153	4.6
Phacelia hastata	2013	35.3	26.7	-2.5	0.66	0.01	108	5.4
(planted fall 2012)	2014	87.7	74.2	-4.9	0.76	0.01	367	7.5
	2015	78.8	2.0	-0.5	0.04	NS		
	Average	67.3	34.3	-2.6	0.9	0.001	180	6.6
Phacelia hastata	2015	-1.3	6.3		0.88	0.001	49	8
(planted fall 2014)	2016	82.5	21.3	-2.6	0.72	0.01	125.2	4.0
	Average	41.2	12.8	-1.2	0.73	0.01	75.4	5.3
Phacelia linearis	2013	121.4	68.3	-5.5	0.69	0.01	333	6.2
	2014	131.9	21.1	-2.7	0.11	NS		
	Average	126.7	44.7	-4.1	0.48	0.1	248	5.4
Thelypodium milleflorum	2014	200.5	22.2	-2.7	0.12	NS		
	2016	121.9	1.4	-1.1	0.35	NS		
	Average	171.7	28.8	-3.9	0.20	NS		

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