PRAIRIE CLOVER SEED PRODUCTION IN RESPONSE TO IRRIGATION

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Summary

Legumes are important components of rangeland vegetation in the Intermountain West because they supply protein to wildlife and livestock and contribute of nitrogen to rangeland productivity. Seed of selected native legumes is needed for rangeland restoration, but cultural practices for native legume production are largely unknown. The seed yield response of two native legume species to irrigation was evaluated starting in 2011. Four biweekly irrigations applying either 0, 1, or 2 inches of water (a total of 0, 4, or 8 inches/season) were tested. Over the 10-year study, *Dalea searlsiae* (Searls' prairie clover) seed yield was maximized by 13 to 21 inches of water applied plus fall, winter, and spring precipitation per season. *Dalea ornata* (Blue Mountain, or western, prairie clover) seed yield was maximized by 11 to 16 inches of water applied plus fall, winter, and spring precipitation per season. Precipitation was higher than average in the 2 years when seed yield of *D. searlsiae* and *D. ornata* did not respond to irrigation.

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 natural rangelands, variations in spring rainfall and soil moisture result in highly variable water stress at flowering, seed set, and seed development. Such stresses for other seed crops are known to compromise seed yield and quality.

Native wildflower plants are not well adapted to croplands; they are often not competitive with weeds in cultivated fields, and this could limit wildflower seed production. Both sprinkler and furrow irrigation can 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 water availability for 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 two native wildflower legume species (Table 1) planted in 2009.

Table 1. Wildflower species in the legume family planted in the fall of 2009, Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common names	Growth habit
Dalea searlsiae	Searls' prairie clover	Perennial
Dalea ornata	Western prairie clover, Blue Mountain prairie clover	Perennial

Materials and Methods

Plant Establishment

Seed of *D. searlsiae* and *D. ornata* was planted in four rows 30 inches apart in a 10-ft-wide strip about 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 2009, two drip tapes 5 ft apart (T-Tape TSX 515-16-340) were buried at 12-inch depth to irrigate the four 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 the two species (Table 1) 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 to 30 seeds/ft. After planting, sawdust was applied in a narrow band over the seed row at 0.26 oz/ft (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. The field was irrigated for 24 hours on December 2, 2009, due to very dry soil conditions.

After the newly planted wildflowers emerged, the row cover was removed in April 2010. The variable irrigation treatments were not applied until 2011.

Each year, plots were hand weeded as necessary. Seed from the middle two rows in each plot was harvested manually (Table 2).

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. The experimental design for each species was a randomized complete block with four replicates. The three treatments were a non-irrigated check, 1 inch of water applied per irrigation, and 2 inches of water applied per irrigation. Each treatment received four irrigations 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. Flowering, irrigation, and harvest dates were recorded (Table 2).

Weed Control

The herbicides pendimethalin (Prowl®), dimethenamid-P (Outlook®), clethodim (Shadow®), and sethoxydim (Poast®) have been used for weed control. Prowl and either Poast or Shadow were applied once per year, usually in the fall. Starting in 2018, Outlook was added to the yearly herbicide application. In addition to herbicides, hand weeding was used as necessary to control weeds.

Seed Weevil Control

Harvested seed pods of *D. ornata* and *D. searlsiae* were extensively damaged from feeding by seed weevils in 2013 and 2014, indicating that control measures during and after flowering would be necessary to maintain seed yields. On May 21, 2015, Capture® 2EC at 6.4 oz/acre (0.1 lb ai/acre) and Rimon® at 12 oz/acre (0.08 lb ai/acre) were broadcast in the evening to minimize harm to pollinators. On May 28, 2015, Rimon at 12 oz/acre was broadcast in the evening to minimize harm to pollinators. Seed beetles were not observed during flowering in 2016–2020.

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 $y = a + b \cdot x + c \cdot x^2$, where a is the intercept, b is the linear parameter, and c is the quadratic parameter. For the quadratic equations, the amount of irrigation (x') that resulted in maximum yield (y') was calculated using the formula $x' = -b/2c$. 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.

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

Adding seasonal precipitation to the irrigation response equation has the potential to provide a closer estimate of the amount of water required for maximum seed yields. 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 accumulated in the previous fall, winter, and spring each year showed large variability (Table 3). The accumulation of growing degree-days (50–86°F) was higher than average from 2012 to 2016 and in 2018, close to average in 2017, 2019, and 2020, and below average in 2011 (Table 3). Flowering and seed harvest were early in 2015 and 2016, probably due to warmer weather and greater accumulation of growing degree-days.

Dalea searlsiae, Searls' Prairie Clover

In 2012, 2014–2016, 2019, and 2020, seed yields showed a quadratic response to irrigation plus fall, winter, and spring precipitation (Table 5). Maximum seed yields were achieved with 15, 17, 17, 15.4, 20.9, and 13.1 inches of water applied plus fall, winter, and spring precipitation in 2012, 2014–2016, 2019, and 2020, respectively. In 2013, seed yields were very low due to seed weevils. In 2013 and 2018, seed yields were maximized by the highest amount of water applied plus fall, winter, and spring precipitation. In 2011, seed yields were highest with no irrigation plus 14.5 inches of fall, winter, and spring precipitation. In 2017, seed yields did not respond to irrigation. Averaged over the 10 years, maximum seed yield was 222 lb/acre achieved with 16.2 inches of water applied plus fall, winter, and spring precipitation.

Dalea ornata, Blue Mountain or Western Prairie Clover

Seed yields showed a quadratic response to irrigation in 2012–2016 and 2018–2020, with maximum seed yields at 16.1, 13.4, 14.9, 14.9, 14.6, 10.8, 15.9, and 12.9 inches of water applied plus fall, winter, and spring precipitation, respectively (Tables 4 and 5). Seed yields in 2011 were highest with no irrigation plus 14.5 inches of fall, winter, and spring precipitation. In 2017, seed yields did not respond to irrigation. Averaged over the 10 years, maximum seed yields were 289 lb/acre achieved with 14.7 inches of water applied plus fall, winter, and spring precipitation.

Dalea spp.

Both *D. searlsiae* and *D. ornata* showed either a negative response or no response to irrigation in 2011 and 2017, years with higher than average fall, winter, and spring precipitation. In 2019, stands of *D. ornata* were observed to be declining differentially by plot. A subjective evaluation of stand of *D. ornata* showed 75, 70, and 50% stand for the non-irrigated, 4 inches/year, and 8 inches/year treatments, respectively, indicating the negative effect of higher amounts of irrigation on stand longevity (LSD 0.05 = 16.3). For *D. searlsiae*, stands were 73, 81, and 76% for the non-irrigated, 4 inches/year, and 8 inches/year treatments, respectively, with no statistically significant differences. While the vigor of *D. searlsiae* and *D. ornata* has slowly declined in the last few years, the low yield in 2020 could have been exacerbated by the higher than average rainfall in May and June, which is the main flowering period.

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Table 2. Native wildflower flowering, irrigation, and seed harvest dates by species, Malheur Experiment Station, Oregon State University, Ontario, OR, 2011–2020.

		Flowering			Irrigation		
Species	Year	Start	Peak	End	Start	End	Harvest
Dalea searlsiae							
	2011	8-Jun	20-Jun	20-Jul	27-May	6-Jul	21-Jul
	2012	23-May	10-Jun	30-Jun	11-May	21-Jun	10-Jul
	2013	13-May		15-Jun	8-May	19-Jun	29-Jun
	2014	15-May	4-Jun	24-Jun	6-May	17-Jun	1-Jul
	2015	13-May	26-May	16-Jun	5-May	17-Jun	22-Jun
	2016	11-May	28-May	10-Jun	3-May	14-Jun	16-Jun
	2017	23-May	7-Jun	30-Jun	23-May	6-Jul	3-Jul
	2018	12-May		15-Jun	16-May	27-Jun	25-Jun
	2019	10-May	28-May	20-Jun	9-May	27-Jun	24-Jun
	2020	10-May	22-May	20-Jun	9-May	18-Jun	24-Jun
Dalea ornata							
	2011	8-Jun	20-Jun	20-Jul	27-May	6-Jul	22-Jul
	2012	23-May	10-Jun	30-Jun	11-May	21-Jun	11-Jul
	2013	13-May	21-May	15-Jun	8-May	19-Jun	28-Jun
	2014	15-May	4-Jun	24-Jun	6-May	17-Jun	1-Jul
	2015	5-May	26-May	22-Jun	5-May	17-Jun	25-Jun
	2016	3-May	26-May	10-Jun	3-May	14-Jun	13-Jun
	2017	23-May	7-Jun	29-Jun	23-May	6-Jul	5-Jul
	2018	12-May		13-Jun	16-May	27-Jun	25-Jun
	2019	10-May	28-May	28-Jun	9-May	27-Jun	25-Jun
	2020	10-May	22-May	20-Jun	9-May	18-Jun	1-Jul

Table 3. Early season precipitation and growing degree-days, Malheur Experiment Station, Ontario, OR, 2011–2020.

	Precipitation (inch)			Growing degree-days (50–86°F)
Year	Spring	Spring + winter	Spring + winter + fall	Jan–July
2011	4.8	9.3	14.5	1533
2012	2.6	6.1	8.4	1979
2013	0.9	2.4	5.3	2064
2014	1.7	5.1	8.1	2112
2015	3.2	5.9	10.4	2327
2016	2.2	5.0	10.1	2138
2017	4.0	9.7	12.7	1962
2018	1.9	4.9	5.8	2075
2019	4.7	10.2	12.9	1912
2020	4.3	6.6	12.8	1991
10-year average:	3.0	6.5	10.1	27-year average: 1917

Table 4. Native wildflower seed yield in response to irrigation rate (inches/season), Malheur Experiment Station, Oregon State University, Ontario, OR, 2011–2019.

Species	Year	0 inches	4 inches	8 inches	LSD (0.05)[a]
		--------------------- lb/acre	---------------------		
Dalea searlsiae					
	2011	262.7	231.2	196.3	50.1
	2012	175.5	288.8	303.0	93.6
	2013	14.8	31.7	44.4	6.1
	2014	60.0	181.4	232.2	72.9
	2015	221.2	330.7	344.2	68.3
	2016	148.7	238.8	222.3	56.0
	2017	222.2	223.6	206.2	NS
	2018	243.9	307.8	329.6	74.9
	2019	166.8	218.6	233.3	51.1
	2020	70.6	151.5	94.0	25.7
	Average	157.2	207.5	221.2	28.3
Dalea ornata					
	2011	451.9	410.8	351.7	NS
	2012	145.1	365.1	431.4	189.3
	2013	28.6	104.6	130.4	38.8
	2014	119.4	422.9	476.3	144.1
	2015	212.9	396.7	267.2	109.6
	2016	246.3	307.9	312.4	NS
	2017	328.2	347.0	270.1	NS
	2018	71.4	159.1	129.7	NS
	2019	213.8	256.6	122.6	61.2
	2020	45.0	107.1	51.5	42.6
	Average	188.4	284.3	254.9	46.4

[a]NS = not significant.

Table 5. Regression analysis for native wildflower seed yield (y) in response to irrigation (x) (inches/season) plus fall, winter, and spring precipitation 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, 2011–2020.

Year	intercept	linear	quadratic	R^2	P^a	Maximum yield	Water applied plus precipitation for maximum yield	Precipitation, fall, winter, spring
Dalea searlsiae								
						lb/acre	inches/season	inches
2011	383.3	-8.3		0.49	0.05	263.3	14.5	14.5
2012	-384.4	92.7	-3.1	0.62	0.05	309.3	15.0	8.4
2013	-4.1	3.7		0.54	0.01	45.1	13.3	5.3
2014	-400.8	74.8	-2.2	0.79	0.001	234.0	17.0	8.1
2015	-515.3	101.9	-3.0	0.56	0.05	350.4	17.0	10.4
2016	-548.3	102.8	-3.3	0.56	0.05	245.2	15.4	10.1
2017	92.1	17.7	-0.6	0.04	NS			12.7
2018	85.3	8.6		0.31	0.10	203.5	13.8	5.8
2019	-247.9	55.1	-1.3	0.67	0.01	327.1	20.9	12.9
2020	-593.9	113.6	-4.3	0.86	0.00	152.0	13.1	12.8
Average	-167.6	48.0	-1.5	0.68	0.01	222.1	16.2	10.1
Dalea ornata								
2011	635.9	-12.5		0.11	NS	454.9	14.5	14.5
2012	-815.6	154.8	-4.8	0.65	0.01	431.8	16.1	8.4
2013	-149.4	41.9	-1.6	0.88	0.001	130.4	13.4	5.3
2014	-1258.9	233.6	-7.8	0.87	0.001	486.6	14.9	8.1
2015	-1597.0	267.3	-8.9	0.64	0.05	399.0	14.9	10.4
2016	-1096.9	203.5	-6.9	0.55	0.10	393.0	14.6	10.1
2017	-368.8	92.9	-3.0	0.13	NS			12.7
2018	-262.0	78.8	-3.7	0.56	0.10	162.7	10.8	5.8
2019	-1124.5	175.0	-5.5	0.71	0.01	263.0	15.9	12.9
2020	-505.2	94.9	-3.7	0.53	0.05	107.1	12.9	12.8
Average	-553.6	114.8	-3.9	0.77	0.01	288.7	14.7	10.1

[a]NS = not significant. There was no statistically significant trend in seed yield in response to the amount of irrigation.