

BEEPLANT SEED YIELD IN RESPONSE TO MODEST IRRIGATION

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Summary

Beeplants (*Cleome* spp.) are annual native range species in the Intermountain West. Beeplant is visited by many classes of pollinators and are thought to be supportive of a wide range of pollinators. Beeplant seed is desired for rangeland restoration activities, but little cultural practice information is known for its seed production. The seed yield response of *Cleome serrulata* (Rocky Mountain beeplant) and *C. lutea* (yellow spiderflower or yellow beeplant) to irrigation was studied. Four biweekly irrigations applying either 0, 1, or 2 inches of water (total of 0, 4, or 8 inches/season) were evaluated over multiple years. Beeplant stands were established through fall plantings each year and were maintained without weed competition. *Cleome serrulata* seed yield was maximized by 8 inches of water applied per season in 2011, but did not respond to irrigation in the following years (2012-2018). *Cleome lutea* seed yield was highest with no irrigation in 2016. *Cleome lutea* seed yield did not respond to irrigation in 2012, 2014, 2015, and 2018. *Cleome lutea* stands were lost to flea beetles in 2013 and to poor emergence in 2017. Flea beetle control is essential for seed production.

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, the annual variation in spring rainfall and soil moisture results 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; they do not compete well with crop weeds in cultivated fields, which could also limit their 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 *Cleome serrulata* (Rocky Mountain beeplant) and *C. lutea* (yellow beeplant).

Materials and Methods

Plant establishment

Each species was planted in separate strips containing four rows 30 inches apart (a 10-ft-wide strip) and 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 2010, 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.

Starting in 2010, seed of *Cleome serrulata* was planted in mid-November each year 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 in the same location each year. 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. Starting in 2011, seed of *C. lutea* was also planted each year. After the newly planted wildflowers had emerged, the row cover was removed in April each year.

Starting in 2013, each spring after the row cover was removed, bird netting was 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.

Flea beetle control

An unidentified species of flea beetle was observed feeding on leaves of *Cleome serrulata* and *C. lutea* in April 2012. On April 29, 2012, all plots of *C. serrulata* and *C. lutea* were sprayed with Capture[®] at 5 oz/acre to control flea beetles. On June 11, 2012, *C. serrulata* was again sprayed with Capture at 5 oz/acre to control a reinfestation of flea beetles.

Flea beetle feeding occurred earlier in 2013 than in 2012. Upon removal of the row cover in March 2013, the flea beetle damage for both species at seedling emergence was extensive and resulted in full stand loss. Flea beetles were not observed on either species in 2014.

On March 20, 2015, after removal of the row cover, all plots of *C. serrulata* and *C. lutea* were sprayed with Capture at 5 oz/acre to control flea beetles. On April 3, 2015, all plots of *C. serrulata* and *C. lutea* were sprayed with Entrust[®] at 2 oz/acre (0.03 lb ai/acre) to control flea beetles.

On March 18, 2016, after removal of the row cover, all plots of *C. serrulata* and *C. lutea* were sprayed with Radiant[®] at 8 oz/acre and on April 6, all plots were sprayed with Capture at 5 oz/acre to control flea beetles. On June 30, all plots of *C. serrulata* were sprayed with Sivanto[®] at 14 oz/acre to control flea beetles.

The following insecticides were applied to both species for flea beetle control in 2017: April 11, Radiant at 8 oz/acre; May 4, Capture at 5 oz/acre; July 14, Capture at 5 oz/acre and Rimon[®] at 12 oz/acre; July 25 and August 4, Rimon at 12 oz/acre.

The insecticide Agri-Mek® at 16 oz/acre was applied on April 18, 2018 to both species for flea beetle control. Flea beetles were not observed on *C. lutea* after April 18. The following insecticides were applied to *C. serrulata* for flea beetle control: Capture at 5 oz/acre on April 27, 2018 and Rimon at 12 oz/acre on June 13.

Weeds were controlled by hand weeding as necessary.

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 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. Flowering, irrigation, and harvest dates were recorded (Table 1). In 2014, after the four bi-weekly irrigations ended, *C. serrulata* and *C. lutea* received three additional bi-weekly irrigations starting on August 12 in an attempt to extend the flowering and seed production period. On August 12, 50 lb nitrogen/acre, 30 lb phosphorus/acre, and 0.2 lb iron/acre were applied through the drip tape to all *Cleome* plots.

Flowering and harvest

The two species have a long flowering and seed-set period (Table 1), making mechanical harvesting difficult. Mature seed pods were harvested manually 2 to 4 times each year.

Table 1. *Cleome serrulata* and *C. lutea* flowering, irrigation, and seed harvest dates by species. Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Year	Flowering dates			Irrigation dates		Harvest
		Start	Peak	End	Start	End	
<i>Cleome serrulata</i>	2011	25-Jun	30-Jul	15-Aug	21-Jun	2-Aug	26-Sep
	2012	12-Jun	30-Jun	30-Jul	13-Jun	25-Jul	24-Jul to 30-Aug
	2013	Full stand loss					
	2014	4-Jun	24-Jun	22-Jul	20-May	1-Jul	11-Jul to 30-Jul
	2015	20-May	24-Jun	15-Sep	20-May	30-Jun	1-Jul to 15-Aug
	2016	23-May		20-Sep	16-May	29-Jun	28-Jun to 15-Aug
	2017	7-Jun		29-Sep	6-Jun	15-Sep	31-Jul, 4-Oct
	2018	29-May		1-Oct	30-May	5-Jul	16-Jul to 20-Aug
<i>Cleome lutea</i>	2012	16-May	15-Jun	30-Jul	2-May	13-Jun	12-Jul to 30-Aug
	2013	Full stand loss, flea beetle damage					
	2014	29-Apr	4-Jun	22-Jul	23-Apr	3-Jun	23-Jun to 30-Jul
	2015	8-Apr	13-May	6-Jul	17-Apr	27-May	4-Jun to 30-Jul
	2016	13-Apr	13-May	25-Jul	18-Apr	31-May	14-Jun to 22-Jul
	2017	5-May		10-Aug			poor stand
	2018	23-Apr	13-Jun	20-Aug	3-May	13-Jun	1-Jun to 15-Jul

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.

Results and Discussion

Spring precipitation in 2012 and 2016 was close to the average of 2.9 inches (Table 2). Spring precipitation in 2013 and 2014 was lower than the average and spring precipitation in 2011 and 2017 was higher than the average. The total growing degree-days (50-86°F) in June and July in 2012-2017 were higher than average (Table 2) and were associated with early flowering and seed harvest.

Cleome serrulata, Rocky Mountain beeplant

In 2011, seed yields increased with increasing irrigation up to the highest tested of 8 inches (Tables 3 and 4). Seed yields did not respond to irrigation the other years. There was no plant stand in 2013 due to early, severe flea beetle damage. The additional irrigations starting on August 12, 2014 did result in an extension/resumption of flowering, but seed harvested in mid-

October was not mature. Flowering in 2015-2017 continued through the end of September, but as in 2014, seed set in September of 2015 and 2016 did not mature. Seed set in September 2017 matured and was harvested. Seed set and seed production were extremely poor in 2016. Continued flea beetle infestations could have caused the poor seed set. A more intensive control program than the three insecticide applications in 2016 might have been necessary. Birds were also observed feeding on seedpods and might have been responsible for the low seed yields. Five insecticide applications were made in 2017. Seed yields in 2017 were higher than in 2016 and similar to 2014 and 2015.

The year 2011 had the highest seed yield and also had the lower than average accumulated growing degree-days, suggesting the possibility of a negative effect of higher temperatures on sustained flowering and seed set. All other years (2012-2018) had higher than average growing degree-days and low yields.

***Cleome lutea*, yellow spiderflower or yellow beeplant**

Seed yields did not respond to irrigation in 2012, 2014, 2015, or 2018 (Tables 3 and 4). In 2016 seed yields were highest with no irrigation. There was no plant stand in 2013. Early attention to flea beetle control is essential for *C. lutea* seed production. The additional irrigations starting on August 12, 2014 did not result in an extension or resumption of flowering. In 2017, emergence was poor and uneven and did not allow an evaluation of irrigation responses.

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Table 2. Early season precipitation and growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2018.

Year	Precipitation (inch)			Growing degree-days (50-86°F)
	Spring	Winter +spring	Fall + winter + spring	March - August
2011	4.8	9.3	14.5	2222
2012	2.6	6.1	8.4	2664
2013	0.9	2.4	5.3	2774
2014	1.7	5.1	8.1	2775
2015	3.2	5.9	10.4	2949
2016	2.2	5.0	10.1	2779
2017	4.0	9.7	12.7	2668
2018	1.9	4.9	5.8	2729
8-year average:	2.7	6.1	9.4	25-year average: 2560

Table 3. *Cleome serrulata* and *C. lutea* seed yield (lb/acre) in response to irrigation rate (inches/season). Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2018.

Species	Year	Irrigation rate			LSD (0.05)
		0 inches	4 inches	8 inches	
		----- lb/acre -----			
<i>Cleome serrulata</i>	2011	446.5	499.3	593.6	100.9 ^a
	2012	184.3	162.9	194.7	NS ^b
	2013	No stand			
	2014	66.3	80	91.3	NS
	2015	54.0	41.0	37.9	NS
	2016	0.8	2.1	1.6	NS
	2017	46.5	52.3	34.8	NS
	2018	0.6	0.7	0.5	NS
	Average	100.2	105.1	119.4	NS
<i>Cleome lutea</i>	2012	111.7	83.7	111.4	NS
	2013	No stand			
	2014	207.1	221.7	181.7	NS
	2015	136.9	80.5	113.0	NS
	2016	65.6	48.9	35.0	18.7
	2017	poor stand			
	2018	1.4	0.6	0.7	NS
		Average	104.5	87.1	88.4

^aLSD (0.10).

^bNot significant: There was no statistically significant trend in seed yield in response to the amount of irrigation.

Table 4. Regression analysis for *Cleome serrulata* and *C. lutea* seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + b \cdot x + c \cdot x^2$. Malheur Experiment Station, Oregon State University, Ontario, OR, 2011-2018.

<i>Cleome serrulata</i>							
Year	intercept	linear	quadratic	R^2	P	Maximum yield	Water applied for 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 ^a		
2014	66.7	3.1		0.16	NS		
2015	52.4	-2.0		0.08	NS		
2016	0.8	0.6	-0.1	0.19	NS		
2017	46.5	4.4	-0.7	0.11	NS		
2018	0.6	0.04	-0.01	0.06	NS		
Average	98.6	2.4		0.32	0.1	117.8	8

<i>Cleome lutea</i>							
Year	intercept	linear	quadratic	R^2	P	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2012	102.4	-0.031		0.01	NS		
2014	207.1	10.4	-1.7	0.2	NS		
2015	122.0	-3.0		0.08	NS		
2016	65.2	-3.8		0.45	0.05	65.2	0.0
2018	1.2	-0.1		0.10	NS		
Average	101.4	-2.0		0.2	NS		

^aNot significant.