IRRIGATION REQUIREMENTS FOR *LOMATIUM* SEED PRODUCTION

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Summary

Lomatium species are important botanical components in the rangelands of the Intermountain West. Relatively little is known about the cultural practices necessary to produce *Lomatium* seed for use in rangeland restoration activities. The seed yield response to four biweekly irrigations applying either 0, 1, or 2 inches of water (total of 0, 4, or 8 inches/season) was evaluated for four *Lomatium* species over multiple years starting in 2007. In order to try to improve the accuracy of estimated irrigation water requirements, seed yield responses to irrigation plus precipitation during the previous spring; winter and spring; and fall, winter, and spring were also evaluated. On average, over nine seed production seasons, *Lomatium dissectum* (fernleaf biscuitroot) seed yield was maximized by 7.7 to 9.5 inches of water applied plus spring precipitation depending on the seed source. On average, over 11 seed production seasons, *L. grayi* (Gray's biscuitroot) seed yield was maximized by 14.3 inches of water applied plus fall, winter, and spring precipitation. On average, over 11 seed production seasons, *L. triternatum* (nineleaf biscuitroot) seed yield was maximized by 12.4 inches of water applied plus spring precipitation. Over six seed production seasons, *L. nudicaule* (barestem biscuitroot) seed yield responded to irrigation only in 2017. In four seed production seasons, seed yield of *L. suksdorfii* (Suksdorf's desertparsley) responded to irrigation only in 2015.

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 production over years.

In native rangelands, the natural 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 and often are not competitive with crop weeds in cultivated fields, which could limit wildflower seed production. Supplemental water can be provided by sprinkler or furrow irrigation systems, but these irrigation systems risk further encouraging weeds. Sprinkler and furrow irrigation can lead to the loss of plant stand and seed production due to fungal pathogens. Burying drip tapes at 12-inch depth and avoiding wetting the soil surface could help 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 five *Lomatium* species (Table 1).

Subsurface drip irrigation systems were tested for native seed production because they have two potential strategic advantages: a) low water use, and b) the buried drip tape provides water to the plants at depth, precluding most irrigation-induced stimulation of weed seed germination on the soil surface and keeping water away from native plant tissues that are not adapted to a wet environment.

Table 1. *Lomatium* species planted in the drip irrigation trials at the Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Common names
Lomatium dissectum	fernleaf biscuitroot
Lomatium triternatum	nineleaf biscuitroot, nineleaf desertparsley
Lomatium grayi	Gray's biscuitroot, Gray's lomatium
Lomatium nudicaule	barestem biscuitroot, barestem lomatium
Lomatium suksdorfii	Suksdorf's desertparsley

Materials and Methods

Plant establishment

Seed of *Lomatium dissectum*, *L. grayi,* and *L. triternatum* was received in late November in 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in fall 2004, but due to excessive rainfall in October, ground preparation was not completed and planting was postponed to early 2005. To try to ensure germination, we submitted the seed 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, seed of *Lomatium grayi* and *L. triternatum* started to sprout.

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 the three species (*Lomatium dissectum*, *L. grayi*, and *L. triternatum*) 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 0.5-inch depth. The trial was irrigated from March 4 to April 29 with a minisprinkler system (R10 Turbo Rotator, Nelson Irrigation Corp., Walla Walla, WA) 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. *Lomatium triternatum* and *L. grayi* started emerging on March 29. Beginning on June 24, the field was irrigated with the drip irrigation 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 *Lomatium triternatum* and *L. grayi* were uneven; *L. dissectum* did not emerge. None of the species flowered in 2005. In early October 2005, more seed was received from the Rocky Mountain Research Station for replanting. The entire row lengths were replanted using the planter on October 26, 2005. In spring 2006, the plant stands were excellent.

On November 25, 2009 seed of *Lomatium nudicaule*, *L. suksdorfii*, and three selections of *L. dissectum* (LODI 38, LODI 41, and seed from near Riggins, ID) 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.

Irrigation for seed production

In April 2006 (April 2010 for the species and selections planted in 2009) each planted strip of each species was divided into plots 30 ft long. 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 applied approximately every 2 weeks starting with 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. After each irrigation, the amount of water applied was read on a water meter and recorded to ensure correct water applications.

Irrigation dates are found in Table 2. In 2007, irrigation treatments were inadvertently continued after the fourth irrigation. Irrigation treatments for all species were continued until the last irrigation on June 24, 2007.

Flowering, harvesting, and seed cleaning

Flowering dates for each species were recorded (Table 2). Each year, the middle two rows of each plot were harvested manually when seed of each species was mature (Table 2). Seed was cleaned manually.

Cultural practices in 2006

On October 27, 2006, 50 lb phosphorus (P)/acre and 2 lb zinc (Zn)/acre were injected through the drip tape to all plots. On November 11, 100 lb nitrogen (N)/acre as urea was broadcast to all plots. On November 17, all plots had Prowl® at 1 lb ai/acre broadcast on the soil surface. Irrigations for all species were initiated on May 19 and terminated on June 30.

Cultural practices in 2007

Irrigations for each species were initiated and terminated on different dates (Table 2).

Cultural practices in 2008

On November 9, 2007 and on April 15, 2008, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2009

On March18, Prowl at 1 lb ai/acre and Volunteer® at 8 oz/acre were broadcast on all plots for weed control. On April 9, 50 lb N/acre and 10 lb P/acre were applied through the drip irrigation system to the three *Lomatium* spp.

On December 4, 2009, Prowl at 1 lb ai/acre was broadcast for weed control on all plots.

Cultural practices in 2010

On November 17, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2011

On May 3, 2011, 50 lb N/acre was applied to all *Lomatium* spp. plots as URAN (urea ammonium nitrate) injected through the drip tape. On November 9, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2012

Iron deficiency symptoms were prevalent in 2012. Liquid fertilizer was injected containing 50 lb N/acre, 10 lb P/acre, and 0.3 lb iron (Fe)/acre using a brief pulse of water through the drip irrigation system to all plots on April 13. On November 7, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2013

Liquid fertilizer was injected containing 20 lb N/acre, 25 lb P/acre, and 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on March 29. On April 3, Select Max® at 32 oz/acre was broadcast for grass weed control on all plots.

Cultural practices in 2014

On February 26, Prowl at 1 lb ai/acre and Select Max at 32 oz/acre were broadcast on all plots for weed control. Liquid fertilizer was injected containing 20 lb N/acre, 25 lb P/acre, and 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on April 2.

Cultural practices in 2015

On March 13, Prowl at 1 lb ai/acre was broadcast on all plots for weed control. Liquid fertilizer was injected containing 20 lb N/acre, 25 lb P/acre, and 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on April 15. On November 6, Prowl at 1 lb ai/acre and Roundup® at 24 oz/acre were broadcast on all plots for weed control.

Cultural practices in 2016

Liquid fertilizer was injected containing 20 lb N/acre, 25 lb P/acre, and 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on March 31. On October 27, Prowl H_2O at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2017

On March 28, Prowl H_2O at 1 lb ai/acre and Poast® at 0.75 lb ai/acre were broadcast on all plots for weed control. Liquid fertilizer was injected containing 0.3 lb Fe/acre using a brief pulse of water through the drip irrigation system to all plots on April 4.

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 amounts 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 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 occurred the prior year.

Adding the seasonal precipitation to the irrigation response equation potentially could provide a closer estimate of the amount of water required for maximum seed yields of the *Lomatium* 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. For species with few years where a yield response to irrigation existed, yield responses are reported as a function of water applied.

Results and Discussion

Spring precipitation in 2012, 2015, and 2016 was close to the average of 2.8 inches (Table 3). Spring precipitation in 2009-2011 and 2017 was higher, and spring precipitation in 2007, 2008, 2013, and 2014 was lower than average. The accumulated growing degree-days (50-86°F) from January through June in 2006, 2007, and 2013-2016 were higher than average (Table 3). The high accumulated growing degree-days in 2015 probably caused early harvest dates (Table 2).

Flowering and seed set

Lomatium grayi and *L. triternatum* started flowering and producing seed in 2007 (second year after fall planting in 2005, Tables 2 and 4). *Lomatium dissectum* started flowering and producing seed in 2009 (fourth year after fall planting in 2005). *Lomatium nudicaule* started flowering and produced seed in 2012 (third year after fall planting in 2009), and *L. suksdorfii* started flowering and produced seed in 2013 (fourth year after fall planting in 2009).

Seed yields

***Lomatium dissectum*, fernleaf biscuit root**

Lomatium dissectum had very little vegetative growth during 2006-2008, and produced very few flowers in 2008. All the *Lomatium* species tested were affected by *Alternaria* fungus, but the infection was greatest on the *L. dissectum* selection planted in this trial. This infection delayed *L. dissectum* plant development. In 2009, vegetative growth and flowering were improved.

Seed yields of *L. dissectum* showed a quadratic response to irrigation rate plus spring precipitation in 2009-2011, 2013-2015, and 2017 (Tables 4 and 6). In 2012, seed yields of *L. dissectum* did not respond to irrigation. In 2016, seed yield increased linearly with increasing irrigation rate plus spring precipitation. Averaged over the 8 years, seed yield showed a quadratic response to irrigation rate plus spring precipitation and was estimated to be maximized at 999 lb/acre/year by spring precipitation plus irrigation of 9.5 inches.

Lomatium dissectum Riggins selection

The Riggins selection *L. dissectum* started flowering in 2013, but only in small amounts. Seed yields of this selection showed a quadratic response to irrigation rate plus spring precipitation in 2014 and 2016 (Tables 5 and 7). Seed yields were estimated to be maximized by 6.5 inches of applied water plus spring precipitation in 2014. Seed was inadvertently not harvested in 2015. In 2016, seed yields were estimated to be maximized by 7.5 inches of applied water plus spring precipitation. In 2017, seed yields were estimated to be maximized by 8 inches of applied water plus spring precipitation. Over years, seed yields were estimated to be maximized by 9.3 inches of applied water plus spring precipitation.

Lomatium dissectum selections LODI 38 and LODI 41

Lomatium dissectum 38 and 41started flowering in 2013, but only in small amounts. Seed yields of LODI 38 did not respond to irrigation in 2014-2017 (Tables 5 and 7) and seed yields of LODI 41 did not respond to irrigation in 2014 and 2016. In 2015 and 2017, seed yields of LODI 41 showed a quadratic response to irrigation rate (Tables 5 and 7). Seed yields of LODI 41 were estimated to be maximized by 8.1 inches of applied water plus spring precipitation in 2015 and by 10.4 inches of applied water plus spring precipitation in 2017. Over years, seed yields were estimated to be maximized by 7.7 inches of applied water plus spring precipitation.

Lomatium grayi, Gray's biscuitroot

Seed yields of *L. grayi* showed a quadratic response to irrigation rate plus fall, winter, and spring precipitation in all years from 2007 through 2017, except in 2007, 2009, 2013, and 2017 (Tables 4 and 6). In 2007, 2009, and 2013, seed yield showed a positive linear response to water applied plus precipitation. In 2010, 2011, and 2017 seed yields did not respond to irrigation. In 2010, seed yield did not respond to irrigation, possibly because of the unusually wet spring of 2010. Rodent damage was a further complicating factor in 2010 that compromised seed yields. Extensive vole damage occurred over the 2009-2010 winter. The affected areas were transplanted with 3-year-old *L. grayi* plants from an adjacent area in the spring of 2010. To reduce the habitat attractiveness to voles, all of the *Lomatium* plants were mowed after becoming dormant in early fall of 2010 and in each subsequent year. In 2011 and 2017, seed yield again did not respond to irrigation. The spring of 2011 was unusually cool and wet and the winter and spring of 2017 had higher than average precipitation. On average, seed yields of *L. grayi* were maximized at 730 lb/acre by 14.3 inches of applied water plus fall, winter, and spring precipitation.

Lomatium triternatum, nineleaf biscuitroot

Seed yields of *L. triternatum* showed a quadratic response to irrigation plus spring precipitation from 2008 through 2013 (Tables 4 and 6). In 2007 and 2014-2016, seed yield showed a positive linear response to water applied plus spring precipitation. In 2017, seed yields did not respond to irrigation, probable due to heavy winter and spring precipitation. On average, seed yields of *L. triternatum* were maximized at 1,213 lb/acre by 12.4 inches of applied water plus spring precipitation.

***Lomatium nudicaule,* barestem biscuitroot**

Seed yields did not respond to irrigation from 2012 to 2016 (Tables 4 and 6). In 2017, seed yields showed a quadratic response to irrigation rate. Seed yields in 2017 were 212 lb/acre with 8 inches of applied water.

***Lomatium suksdorfii,* Suksdorf's desert parsley**

Lomatium suksdorfii started flowering in 2013, but only in small amounts. In the 4 years that seed was harvested, seed yields of *L. suksdorfii* responded to irrigation only in 2015 (Tables 5 and 7). In 2015, seed yield increased linearly with increasing water applied up to the highest amount of water applied, 8 inches.

Management applications

This report describes irrigation practices that can be immediately implemented by seed growers. Multi-year summaries of research findings are found in Tables 4-8.

Conclusions

The *Lomatium* species were relatively slow to produce ample seed. *Lomatium grayi* and *L. triternatum* had reasonable seed yields starting in the second year, *L. dissectum* and *L. nudicaule* were productive in their fourth year, while *L. suksdorfii* was only moderately productive in the fifth year after planting. The delayed maturity affects the cost of seed production, but these species have proven to be strong perennials, especially when protected from rodent damage.

Due to the arid environment, supplemental irrigation may often be required for successful flowering and seed set because soil water reserves may be exhausted before seed formation. The total irrigation requirements for these arid-land species were low and varied by species (Table 8). *Lomatium nudicaule* and *L. suksdorfii* did not respond to irrigation most years; natural rainfall was sufficient to maximize its seed production in the absence of weed competition. *Lomatium dissectum* required approximately 6 inches of irrigation; *L. grayi* and *L. triternatum* responded quadratically to irrigation with the optimum varying by year. Accounting for precipitation improved the accuracy in the estimates of irrigation necessary for optimal seed production for *L. grayi*, *L. triternatum*, and *L. dissectum.*

Acknowledgements

This project was funded by the U.S. Forest Service Great Basin Native Plant Project, U.S. Bureau of Land Management, Oregon State University, Malheur County Education Service District, and supported by Formula Grant nos. 2017-31100-06041 and 2017-31200-06041 from the USDA National Institute of Food and Agriculture.

Table 2. *Lomatium* flowering, irrigation, and seed harvest dates by species in 2006-2017, Malheur Experiment Station, Oregon State University, Ontario, OR. Continued on next page.

		Flowering			Irrigation		
Species	Year	Start	Peak	End	Start	End	Harvest
Lomatium dissectum	2006	No flowering			19-May	30-Jun	
	2007	No flowering			5-Apr	24-Jun	
	2008	Very little flowering			10-Apr	29-May	
	2009	10-Apr		7-May	20-Apr	28-May	16-Jun
	2010	25-Apr		20-May	15-Apr	28-May	21-Jun
	2011	8-Apr	25-Apr	10-May	21-Apr	7-Jun	20-Jun
	2012	9-Apr	16-Apr	16-May	13-Apr	24-May	4-Jun
	2013	10-Apr		25-Apr	4-Apr	16-May	4-Jun
	2014	28-Mar		21-Apr	7-Apr	20-May	2-Jun
	2015	1-Apr		24-Apr	1-Apr	13-May	26-May (0 in), 1-Jun (4, 8 in)
	2016	25-Mar		24-Apr	31-Mar	9-May	26-May
	2017	7-Apr		8-May	19-Apr	6-Jun	6-Jun
Lomatium grayi	2006	No flowering			19-May	30-Jun	
	2007	5-Apr		10-May	5-Apr	24-Jun	30-May, 29-Jun
	2008	25-Mar		15-May	10-Apr	29-May	30-May, 19-Jun
	2009	10-Mar		7-May	20-Apr	28-May	16-Jun
	2010	15-Mar		15-May	15-Apr	28-May	22-Jun
	2011	1-Apr	25-Apr	13-May	21-Apr	7-Jun	22-Jun
	2012	15-Mar	25-Apr	16-May	13-Apr	24-May	14-Jun
	2013	15-Mar		30-Apr	4-Apr	16-May	10-Jun
	2014	28-Mar		2-May	7-Apr	20-May	10-Jun
	2015	1-Mar		28-Apr	1-Apr	13-May	1-Jun
	2016	7-Mar		29-Apr	31-Mar	9-May	1-Jun
	2017	15-Mar		12-May	19-Apr	6-Jun	8-Jun
Lomatium triternatum	2006	No flowering			19-May	30-Jun	
	2007	25-Apr		1-Jun	5-Apr	24-Jun	29-Jun, 16-Jul
	2008	25-Apr		5-Jun	10-Apr	29-May	3-Jul
	2009	10-Apr	7-May	1-Jun	20-Apr	28-May	26-Jun
	2010	25-Apr		15-Jun	15-Apr	28-May	22-Jul
	2011	30-Apr	23-May	15-Jun	21-Apr	7-Jun	26-Jul
	2012	12-Apr	17-May	6-Jun	13-Apr	24-May	21-Jun
	2013	18-Apr		10-May	4-Apr	16-May	4-Jun
	2014	7-Apr	29-Apr	2-May	7-Apr	20-May	4-Jun
	2015	10-Apr	28-Apr	20-May	1-Apr	13-May	7-Jun (0 in), 15-Jun (4, 8 in)
	2016	11-Apr	28-Apr	20-May	31-Mar	9-May	15-Jun
	2017	24-Apr	15-May	30-May	19-Apr	6-Jun	27-Jun

Table 2. Continued. *Lomatium* flowering, irrigation, and seed harvest dates by species in 2006-2017, Malheur Experiment Station, Oregon State University, Ontario, OR.

		Flowering			Irrigation		
Species	Year	Start	Peak	End	Start	End	Harvest
Lomatium nudicaule	2011	No flowering					
	2012	12-Apr	1-May	30-May	18-Apr	30-May	22-Jun
	2013	11-Apr		20-May	12-Apr	22-May	10-Jun
	2014	7-Apr		13-May	7-Apr	20-May	16-Jun
	2015	25-Mar		5-May	1-Apr	13-May	8-Jun
	2016	5-Apr		5-May	11-Apr	23-May	6-Jun
	2017	12-Apr		15-May	19-Apr	6-Jun	19-Jun
Lomatium suksdorfii	2013	18-Apr		23-May			
	2014	15-Apr		20-May	7-Apr	20-May	30-Jun
	2015	3-Apr	27-Apr	10-May	1-Apr	13-May	23-Jun
	2016	5-Apr	27-Apr	31-May	11-Apr	23-May	28-Jun
	2017	17-Apr		2-Jun	19-Apr	6-Jun	19-Jun

Table 3. Precipitation and growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2006-2017.

	Precipitation (inch)			Growing degree-days (50-86°F)
Year	Spring	Winter + spring	Fall + winter + spring	Jan-Jun
2006	3.4	10.1	14.5	1273
2007	1.9	3.8	6.2	1406
2008	1.4	3.2	6.7	1087
2009	4.1	6.7	8.9	1207
2010	4.3	8.4	11.7	971
2011	4.8	9.3	14.5	856
2012	2.6	6.1	8.4	1228
2013	0.9	2.4	5.3	1319
2014	1.7	5.1	8.1	1333
2015	3.2	5.9	10.4	1610
2016	2.2	5.0	10.1	1458
2017	4.0	9.7	12.7	1196
12-year average:	2.9	6.3	9.8	23-year average: 1207

Table 4. Seed yield response to irrigation rate (inches/season) for four *Lomatium* species in 2006 through 2017. Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Year	Irrigation rate 0 inches	4 inches	8 inches	LSD (0.05)
Lomatium dissectum		--------- lb/acre -----			
	2006	---- no flowering ----			
	2007	---- no flowering ----			
	2008	- very little flowering -			
	2009	50.6	320.5	327.8	196.4[b]
	2010	265.8	543.8	499.6	199.6
	2011	567.5	1342.8	1113.8	180.9
	2012	388.1	460.3	444.4	NS
	2013	527.8	959.8	1166.7	282.4
	2014	353.4	978.9	1368.3	353.9
	2015	591.2	1094.7	1376.0	348.7
	2016	1039.4	1612.7	1745.4	564.2
	2017	488.2	713.1	674.4	220.5[b]
9-year average		474.7	923.3	968.5	137.1

Species	Year	Irrigation rate 0 inches	4 inches	8 inches	LSD (0.05)
Lomatium grayi		---------- lb/acre ----------			
	2006	---- no flowering ----			
	2007	36.1	88.3	131.9	77.7[b]
	2008	393.3	1287.0	1444.9	141.0
	2009	359.9	579.8	686.5	208.4
	2010	1035.7	1143.5	704.8	NS
	2011	570.3	572.7	347.6	NS
	2012	231.9	404.4	377.3	107.4
	2013	596.7	933.4	1036.3	NS
	2014	533.1	1418.1	1241.3	672.0
	2015	186.4	576.7	297.6	213.9
	2016	483.7	644.2	322.9	218.7
	2017	333.5	259.5	246.3	NS
11-year average		438.4	718.9	621.6	210.5

Species	Year	Irrigation rate 0 inches	4 inches	8 inches	LSD (0.05)
Lomatium nudicaule		---------- lb/acre ----------			
	2010	---- no flowering ----			
	2011	---- no flowering ----			
	2012	53.8	123.8	61.1	NS
	2013	357.6	499.1	544.0	NS
	2014	701.3	655.6	590.9	NS
	2015	430.6	406.1	309.3	NS
	2016	363.0	403.7	332.5	NS
	2017	53.7	159.7	212.0	49.7
6-year average		326.7	374.7	341.6	NS

Species	Year	Irrigation rate 0 inches	4 inches	8 inches	LSD (0.05)
Lomatium triternatum		---------- lb/acre ----------			
	2006	---- no flowering ----			
	2007	2.3	17.5	26.7	16.9[b]
	2008	195.3	1060.9	1386.9	410.0
	2009	181.6	780.1	676.1	177.0
	2010	1637.2	2829.6	3194.6	309.4
	2011	1982.9	2624.5	2028.1	502.3[b]
	2012	238.7	603.0	733.2	323.9
	2013	153.7	734.4	1050.9	425.0
	2014	240.6	897.1	1496.7	157.0
	2015	403.2	440.8	954.9	446.6
	2016	395.0	475.7	638.4	175.7
	2017	932.8	948.9	1266.2	216.8
11-year average		578.5	1037.5	1211.2	128.2

[a]LSD (0.10)

Table 5. Seed yield response to irrigation rate (inches/season) for two *Lomatium* species in 2014-2017. Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Year	Irrigation rate 0 inches	4 inches	8 inches	LSD (0.05)
		---------- lb/acre ----------			
Lomatium dissectum 'Riggins'	2014	276.8	497.7	398.4	163
	2016	299.1	679.5	592.4	247.4
	2017	315.1	405.1	440.0	87.4
3-year average		297.0	527.4	476.9	141.8
Lomatium dissectum '38'	2014	281.9	356.4	227.1	NS
	2015	865.1	820.9	774.6	NS
	2016	474.8	634.5	620.0	70.3
	2017	398.8	575.0	553.2	NS
4-year average		508.4	596.7	523.7	NS
Lomatium dissectum '41'	2014	222.2	262.4	149.8	NS
	2015	152.2	561.9	407.4	181.4
	2016	238.1	297.7	302.0	NS
	2017	214.9	363.0	377.5	71.0
4-year average		206.9	371.2	309.2	124.8
Lomatium suksdorfii	2014	162.6	180.0	139.8	NS
	2015	829.6	1103.9	1832.0	750.2
	2016	692.6	898.8	467.5	NS
	2017	1315.5	1736.6	1315.5	NS
4-year average		1025.7	979.8	1025.7	NS

Table 6. Regression analysis for native wildflower seed yield (y) in response to irrigation (x) (inches/season) using the equation $y = a + bx + cx^2$ in 2006-2017, and 9- to 11-year averages. 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.

Lomatium dissectum Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2009	-922.0	307.9	-16.9	0.60	0.05	478	9.1	4.1
2010	-178.3	128.3	-5.9	0.51	0.05	514	10.8	4.3
2011	-1669.6	618.7	-31.4	0.86	0.001	1380	9.9	4.8
2012	293.9	43.4	-2.8	0.07	NS			2.6
2013	407.0	148.1	-7.0	0.68	0.01	1186	10.5	0.9
2014	9.7	211.4	-7.4	0.83	0.001	1524	14.3	1.7
2015	24.5	198.4	-6.9	0.78	0.01	1441	14.3	3.2
2016	916.9	88.2		0.42	0.05	1623	10.2	2.2
2017	134.7	139.9	-8.2	0.40	0.10	730	8.5	4.0
Average	-146.8	240.2	-12.6	0.91	0.001	999	9.5	2.9
Lomatium grayi Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus fall, winter, and spring precipitation for maximum yield	Spring, winter, fall precipitation
						lb/acre	inches/season	inch
2007	-36.6	12.0		0.26	0.10	59	14.2	6.19
2008	-2721.1	621.3	-23.0	0.93	0.001	1475	13.5	6.65
2009	17.8	40.8		0.38	0.05	344	16.8	8.8
2010	-2431.4	495.9	-17.1	0.22	NS			11.7
2011	-1335.1	234.7	-7.1	0.07	NS			14.5
2012	-778.8	172.8	-6.2	0.66	0.01	418	13.8	8.4
2013	344.3	55.0		0.25	0.10	1075	13.3	5.3
2014	-4502.3	890.8	-33.2	0.64	0.05	1477	13.4	8.1
2015	-3980.4	617.7	-20.9	0.71	0.01	579	14.8	10.4
2016	-2046.2	403.1	-15.1	0.66	0.01	651	13.4	9.1
2017	461.9	-10.9		0.22	NS			12.7
Average	-1690.8	337.9	-11.8	0.55	0.05	730	14.3	9.8
Lomatium triternatum Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2007	-2.6	3.1		0.52	0.01	28	9.9	1.92
2008	-245.1	332.1	-16.9	0.77	0.01	1390	9.8	1.43
2009	-1148.3	416.1	-22.0	0.83	0.001	824	9.5	4.1
2010	-586.2	625.4	-25.9	0.83	0.001	3196	12.1	4.3
2011	-400.3	684.1	-38.7	0.45	0.10	2623	8.8	4.8
2012	-123.6	158.4	-7.3	0.52	0.05	734	10.8	2.6
2013	-3.8	192.2	-8.3	0.68	0.01	1115	11.6	0.9
2014	-22.7	157.4		0.97	0.001	1509	9.7	1.7
2015	101.8	69.0		0.51	0.01	875	11.2	3.2
2016	313.9	30.4		0.29	0.10	624	10.2	2.2
2017	717.1	41.7		0.20	NS	1217	12.0	4.0
Average	-159.2	221.2	-8.9	0.81	0.001	1213	12.4	2.9

Table 7. Regression analysis for seed yield response to irrigation rate (inches/season) in 2012-2017 for *Lomatium nudicaule, L. suksdorfii*, and three selections of *L. dissectum* planted in 2009. 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.

Lomatium nudicaule

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2012	53.8	34.1	-4.1	0.18	NS		
2013	357.6	47.5	-3.0	0.11	NS		
2014	704.5	-13.8		0.08	NS		
2015	430.6	2.9	-2.3	0.15	NS		
2016	363.0	24.1	-3.5	0.07	NS		
2017	53.7	33.2	-1.7	0.75	0.01	218	9.9
Average	399.2	-1.2		0.01	NS		

Lomatium suksdorfii

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
2014	162.6	11.5	-1.8	0.01	NS		
2015	753.9	125.3		0.43	0.05	1756	8.0
2016	692.6	131.2	-19.9	0.17	NS		
2017	750.7	422.4	-44.0	0.39	NS		
Average	608.9	133.4	-10.2	0.28	NS		

***Lomatium dissectum* 'Riggins'**

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2014	82.1	129.9	-10.0	0.57	0.05	503	6.5	1.7
2016	-113.8	218.4	-14.6	0.63	0.05	703	7.5	2.2
2017	262.3	15.6		0.37	0.05	387	8.0	4.0
Average	-209.5	162.4	-8.8	0.65	0.01	542	9.3	2.8

***Lomatium dissectum* '38'**

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2014	281.9	44.1	-6.4	0.11	NS			1.7
2015	865.4	-11.3		0.01	NS			3.2
2016	474.8	61.7	-5.4	0.32	NS			2.2
2017	398.8	68.8	-6.2	0.38	NS			4.0
Average	508.4	42.2	-5.0	0.1	NS			2.8

***Lomatium dissectum* '41'**

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied plus spring precipitation for maximum yield	Spring precipitation
						lb/acre	inches/season	inch
2014	222.2	29.1	-4.8	0.13	NS			1.7
2015	-587.4	286.5	-17.6	0.67	0.01	576	8.1	3.2
2016	181.3	29.4	-1.7	0.18	NS			2.2
2017	-64.2	86.9	-4.2	0.70	0.01	388	10.4	4.0
Average	-41.3	108.7	-7.1	0.49	0.05	377	7.7	2.8

Table 8. Amount of irrigation water plus precipitation for maximum *Lomatium* seed yield, years to seed set, and life span. A summary of multi-year research findings, Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Optimum amount of irrigation plus precipitation	Critical precipitation period	Years to first seed set	Life span
	inches		from fall planting	years
Lomatium dissectum	7.7-9.5[a]	spring	4	9+
Lomatium grayi	14.3	fall, winter, and spring	2	9+
Lomatium nudicaule	no response in 5 out of 6 years, 8 inches in 2017		3	4+
Lomatium triternatum	12.4	spring	2	9+
Lomatium suksdorfii	no response in 2014, 2016, and 2017, 8 inches irrigation in 2015	undetermined	5	5+

[a]The amount of recommended irrigation plus precipitation varied with the *L. dissectum* seed source.