IRRIGATION REQUIREMENTS FOR SEED PRODUCTION OF FIVE *LOMATIUM* SPECIES IN A SEMI-ARID ENVIRONMENT

Clinton C. Shock, Erik B. G. Feibert, Alicia Rivera, and Lamont D. Saunders, Malheur Experiment Station, Oregon State University, Ontario, OR, 2014
Nancy Shaw and Francis Kilkenny, U.S. Forest Service, Rocky Mountain Research Station, Boise, ID
Ram S. Sampangi, University of Idaho, Parma, ID

Summary

Lomatium species are important 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 restorations activities. The seed yield response of four *Lomatium* species to three irrigation treatments. Each of the *Lomatium* species received four biweekly irrigations applying either 0, 1, or 2 inches of water (total of 0, 4 inches, or 8 inches/season) was evaluated over multiple years. Over 6 seed production seasons, *Lomatium dissectum* seed yield was maximized by 5 to 6 inches of water applied per season in cooler, wetter years and by 8 inches of water applied per season in warmer, drier years. Over 8 seed production seasons, *L. grayi* seed yield was maximized by 0 to 5 inches of water applied per season in cooler, wetter years and by 5 to 8 inches of water applied per season in warmer, drier years. Over 8 seed production seasons, *L. triternatum* seed yield was maximized by 4 to 8 inches of water applied per season in cooler, wetter years and by 8 inches of water applied per season in warmer, drier years. Over three seed production seasons, *L. nudicaule* seed yield did not respond to irrigation. In the single seed production season observed, seed yield of *L. suksdorfii* did not respond to irrigation.

Introduction

Several members of the genus *Lomatium*, the biscuitroots or desert parsleys, including *L. dissectum* (fernleaf biscuitroot), *L. grayi* (Gray's biscuitroot), *L. nudicaule* (barestem biscuitroot) and *L. triternatum* (nineleaf biscuitroot) are recognized as important for use in wildland restoration in the Intermountain West (Shaw and Pellant 2009). In addition, many *Lomatium* species were utilized by Native Americans for their medicinal values (Tilley et al. 2010 a, b, Shock et al. 2012), and evaluation and use of such species as *L. suksdorfii* (Suksdorf's desert parsley) continue today (Lee et al. 1994). Except for *L. suksdorfii*, which is found only in south-central Washington and north-central Oregon, they are widespread in the Intermountain West. They grow in scattered stands in well-drained coarse to fine-textured soils and on scablands, rocky slopes, and open ridges.

Larger-statured and widely distributed *Lomatiums* are valued as restoration species as they are among the earliest wildflowers to green up in early spring. *Lomatiums* provide a source of forage for wildlife (elk, deer, and antelope) and domestic livestock (sheep, cattle) (Ogle and Brazee 2009). Barnett and Crawford (1994) reported that sage-grouse hens ate *Lomatium* leaves and stems, while Drut et al. (1994) found that sage-grouse chicks also consumed *Lomatium*. The *Lomatium* species was not identified for either study. *Lomatiums* are also used by birds, small mammals, pollinators, and other insects (Thompson 1998). *Lomatium* species are long-lived and considered competitive with exotic annuals such as *Bromus tectorum* (cheatgrass) because of their early spring growth and deep taproot system (Tilley 2010a, b).

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 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. They 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, 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. 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 five *Lomatium* species (Table 1).

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 desert parsley
Lomatium grayi	Gray’s biscuitroot, Gray’s lomatium
Lomatium nudicaule	Barestem biscuitroot, Barestem lomatium
Lomatium suksdorfii	Suksdorf’s desert parsley

Materials and Methods

Plant establishment

Seed of *Lomatium dissectum*, *L. grayi*, and *L. triternatum* was received in late November 2004 from the Rocky Mountain Research Station (Boise, ID). The plan was to plant the seed in the fall of 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, the seed was submitted 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* had 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 three species was planted in 30-inch rows using a custom-made plot grain drill with disc openers. All seed was planted at 20-30 seeds/ft of row. The seed was planted 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. *Lomatium 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 plots had the entire row lengths replanted using the planter on October 26, 2005. In the spring of 2006, the plant stands of the replanted species 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 plot grain drill with disk 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 that were 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 March 18, 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, 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, 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 containing 20 lb N/acre, 25 lb P/acre, and 0.3 lb Fe/acre was injected with a brief pulse of water through the drip irrigation system to all plots on April 2.

Table 2. *Lomatium* flowering, irrigation, and seed harvest dates by species in 2006-2014, Malheur Experiment Station, Oregon State University, Ontario, OR.

		Flowering			Irrigation		
Species	Year	start	peak	end	start	end	Harvest
Lomatium dissectum							
	2006				19-May	30-Jun	
	2007				5-Apr	24-Jun	
	2008				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
Lomatium grayi							
	2006				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
Lomatium triternatum							
	2006				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
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

Results and Discussion

Precipitation from January through June in 2009, 2012, and 2014 was close to the average of 5.8 inches (Table 3). Precipitation from January through June in 2006, 2010, and 2011 was higher than the average of 5.8 inches. Precipitation from January through June in 2007, 2008, and 2013 was lower than the average of 5.8 inches The accumulated growing degree-days (50-86°F) from January through June in 2006, 2007, 2013, and 2014 were higher than average (Table 3, Figs. 1 and 2).

Table 3. Early season precipitation and growing degree-days at the Malheur Experiment Station, Oregon State University, Ontario, OR, 2006-2014.

	Precipitation (inches)		Growing degree-days (50-86°F)
Year	Jan-Jun	Apr-Jun	Jan-Jun
2006	9.0	3.1	1120
2007	3.1	1.9	1208
2008	2.9	1.2	936
2009	5.8	3.9	1028
2010	8.3	4.3	779
2011	8.3	3.9	671
2012	5.8	2.3	979
2013	2.6	1.4	1118
2014	5.1	1.6	1109
70-year average	5.8	2.7	1010[a]

[a]24-year average.

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.

Flowering and seed set

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

Seed yields

Lomatium dissectum

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 for *L. dissectum* were improved.

Seed yield of *L. dissectum* showed a linear response to irrigation rate in 2009 (Tables 4 and 6). Seed yield with the 4-inch irrigation rate was significantly higher than with the nonirrigated check, but the 8-inch irrigation rate did not result in a significant increase above the 4-inch rate. In 2010 and 2011, seed yields of *L. dissectum* showed a quadratic response to irrigation rate. Seed yields were estimated to be maximized by 5.4 and 5.1 inches of applied water in 2010 and 2011, respectively. In 2012, seed yields of *L. dissectum* did not respond to irrigation rate. In 2013 and 2014, seed yield increased linearly with increasing irrigation rate up to 8 inches, the highest amount applied. Over the 5 years, seed yield showed a quadratic response to irrigation rate and was estimated to be maximized at 869 lb/acre/year by applying 6.1 inches of water.

Lomatium dissectum **Riggins selection**

L. dissectum Riggins selection started flowering in 2013, but in small amounts. Seed yields of *L. dissectum* Riggins selection showed a quadratic response to irrigation rate in 2014 (Tables 5 and 7). Seed yields were estimated to be maximized by 4.8 inches of applied water in 2014.

Lomatium dissectum **38 and 41**

L. dissectum 38 and 41started flowering in 2013, but in small amounts. Seed yields of the *L. dissectum* lines 38 and 41were not responsive to irrigation in 2014 (Tables 5 and 7).

Lomatium grayi

Lomatium grayi showed a trend for increasing seed yield with increasing irrigation rate in 2007 (Tables 4 and 6). The highest irrigation rate resulted in significantly higher seed yield than the nonirrigated check in 6 of the last 8 years. Seed yields of *L. grayi* were substantially higher in 2008 and 2009. In 2008, seed yields of *L. grayi* showed a quadratic response to irrigation rate. Seed yields were estimated to be maximized by 6.9 inches of water applied in 2008. In 2009, seed yield showed a linear response to irrigation rate. Seed yield with the 4-inch irrigation rate was significantly higher than in the nonirrigated check, but the 8-inch irrigation rate did not result in a significant increase above the 4-inch rate. In 2010, seed yield did not respond to irrigation, possibly because of the unusually wet spring of 2010. A further complicating factor in 2010 that compromised seed yields was rodent damage. Extensive rodent (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 their attractiveness to voles, the plants were mowed after becoming dormant in early fall of 2010 and in each subsequent year. In 2011, seed yield again did not respond to irrigation. The spring of 2011 was unusually cool and wet. In 2012, seed yields of *L. grayi* showed a quadratic response to irrigation rate, with a maximum seed yield at 5.5 inches of applied water. In 2013, seed yield increased linearly with increasing water application, up to 8 inches, the highest amount applied. In 2014, seed yields of *L. grayi* showed a quadratic response to irrigation rate, with a calculated maximum seed yield of 1477 lb/acre at 5.3 inches of applied water. Over 8 years, seed yield of *L. grayi* was estimated to be maximized at 827 lb/acre/year by 5.4 inches of applied water. Most appropriately, irrigation probably should vary according to precipitation.

Lomatium nudicaule

Seed yields did not respond to irrigation in the 3 years of testing (Tables 4 and 6). Seed yields in the range of 350 to 700 lb/acre/year were harvested in 2013 and 2014, the fourth and fifth years after planting.

Lomatium triternatum

Lomatium triternatum showed a trend for increasing seed yield with increasing irrigation rate in 2007 (Tables 4 and 6). The highest irrigation rate resulted in significantly higher seed yield than the nonirrigated check in 7 of the last 8 years. Seed yields of *L. triternatum* were substantially higher in 2008-2011, when seed yields showed a quadratic response to irrigation rate. Seed yields were estimated to be maximized by 8.4, 5.4, 7.8, and 4.1 inches of water applied in 2008, 2009, 2010, and 2011, respectively. In 2012-2014, seed yield increased linearly with increasing water applied up to the highest amount of 8 inches. Over 8 years, seed yield of *L. triternatum* was estimated to be maximized at 1,328 lb/acre/year at 6.9 inches of applied water.

Lomatium suksdorfii

Lomatium suksdorfii started flowering in 2013, but only in small amounts. Seed yields of *L. suksdorfii* did not respond to irrigation in 2014 (Tables 5 and 7).

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 while *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* did not respond to irrigation in these trials. Natural rainfall was sufficient to maximize seed production in the absence of weed competition. *Lomatium dissectum* required approximately 6 inches of irrigation. *Lomatium grayi* and *L. triternatum* responded quadratically to irrigation with the optimum varying by year.

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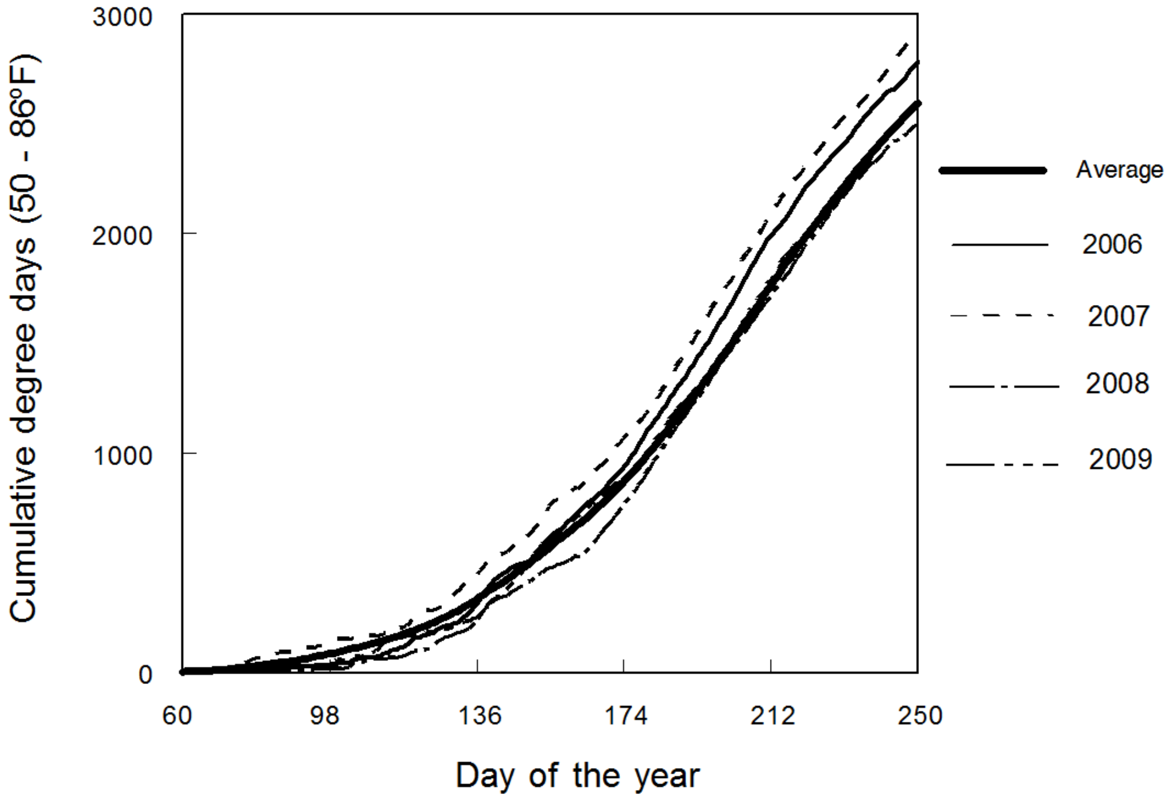

Figure 1. Growing degree days (50-86°F) for 2006-2009 and the 24-year average. Malheur Experiment Station, Oregon State University, Ontario, OR.

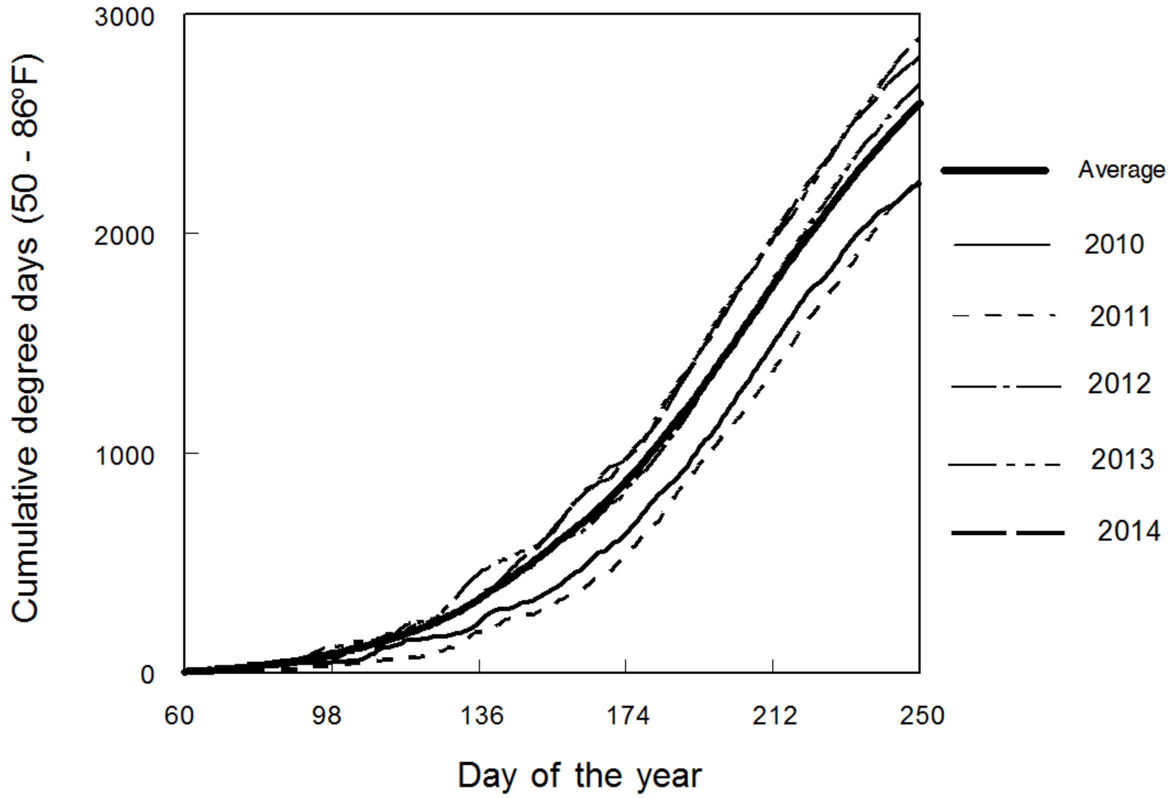

Figure 2. Growing degree-days (50-86°F) for 2010-2014 and the 24-year average. Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 4. Seed yield response to irrigation rate (inches/season) for three *Lomatium* species in 2006-2014. 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
	6-year average	358.9	807.9	820.1	142.7
Lomatium nudicaule					
	2010	---- no flowering ----			
	2011	---- no flowering ----			
	2012	53.8	123.8	61.1	NS
	2013	357.6	499.1	544	NS
	2014	701.3	655.6	590.9	NS
	3-year average	370.9	426.2	398.7	NS

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	1444.9	141
	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
	8-year average	469.6	803.4	746.3	248.3
Lomatium triternatum					
	2006	---- no flowering ----			
	2007	2.3	17.5	26.7	16.9[b]
	2008	195.3	1060.9	1386.9	410
	2009	181.6	780.1	676.1	177
	2010	1637.2	2829.6	3194.6	309.4
	2011	1982.9	2624.5	2028.1	502.3[b]
	2012	238.7	603	733.2	323.9
	2013	153.7	734.4	1050.9	425
	2014	240.6	897.1	1496.7	157
	8-year average	579	1193.4	1311	150.2

[b]LSD (0.10)

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

Species	0 inches	4 inches	8 inches	LSD (0.05)
	--------------------- lb/acre -------------------------			
Lomatium dissectum Riggins selection	276.8	497.7	398.4	163.0
Lomatium dissectum selection 38	281.9	356.4	227.1	NS
Lomatium dissectum selection 41	222.2	262.4	149.8	NS
Lomatium suksdorfii	162.6	180.0	139.8	NS

Table 6. Regression analysis for native wildflower seed yield response to irrigation rate (inches/season) in 2006-2014, and 2- to 9-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.

Year	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
Lomatium dissectum							
						lb/acre	inches/season
2009	86.4	34.6		0.31	0.10	363.2	8.0
2010	265.8	109.8	-10.1	0.68	0.01	564.2	5.4
2011	567.5	319.3	-31.4	0.86	0.001	1379.2	5.1
2012	402.7	7.0		0.04	NS		
2013	565.3	79.9		0.65	0.01	1204.2	8.0
2014	392.7	126.9		0.82	0.001	1407.9	8.0
Average	358.9	166.9	-13.7	0.91	0.001	869.1	6.1
Lomatium grayi							
2007	37.5	12.0		0.26	0.10	133.5	8.0
2008	393.3	315.4	-23.0	0.93	0.001	1474.6	6.9
2009	378.7	40.8		0.38	0.05	705.1	8.0
2010	1035.7	95.3	-17.1	0.22	NS		
2011	608.2	-27.8		0.07	NS		
2012	231.9	68.1	-6.2	0.66	0.01	418.9	5.5
2013	635.6	55.0		0.25	0.10	1075.3	8.0
2014	533.1	354.0	-33.2	0.64	0.05	1477.1	5.3
Average	469.6	132.3	-12.2	0.55	0.05	827.9	5.4
Lomatium nudicaule							
2012	75.9	0.9		0.01	NS		
2013	373.7	23.3		0.1	NS		
2014	704.5	-13.8		0.08	NS		
Average	384.7	3.5		0.01	NS		
Lomatium triternatum							
2007	3.3	3.1		0.52	0.01	27.7	8.0
2008	195.3	283.9	-16.9	0.77	0.01	1387.6	8.4
2009	181.6	237.4	-22.0	0.83	0.001	822.0	5.4
2010	1637.2	401.5	-25.9	0.83	0.001	3193.2	7.8
2011	1982.9	315.1	-38.7	0.45	0.10	2624.3	4.1
2012	277.8	61.8		0.49	0.05	772.2	8.0
2013	197.7	112.2		0.66	0.01	1095.0	8.0
2014	249.6	157.4		0.97	0.001	1508.6	8.0
Average	579.0	215.7	-15.5	0.84	0.001	1328.2	6.9

[a] not significant. There was no statistically significant difference in yield between the non-irrigated plots and the plots receiving 4 or 8 inches of water.

Table 7. Regression analysis for seed yield response to irrigation rate (inches/season) in 2014 for two *Lomatium* species 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.

Species	intercept	linear	quadratic	R^2	*P*	Maximum yield	Water applied for maximum yield
						lb/acre	inches/season
Lomatium dissectum Riggins selection	276.8	95.2	-10.0	0.57	0.05	503.5	4.8
Lomatium dissectum selection 38	281.9	44.1	-6.4	0.11	NS		
Lomatium dissectum selection 41	222.2	29.1	-4.8	0.13	NS		
Lomatium suksdorfii	162.6	11.5	-1.8	0.01	NS		

Table 8. Amount of irrigation water 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	Years to first seed set	Life span
	inches/season	from fall planting	years
Lomatium dissectum	5 in wet years, 8 in dry years	4	8+
Lomatium grayi	0 in wet years, 5 to 8 in dry years	2	8+
Lomatium nudicaule	no response	3	3+
Lomatium triternatum	average of 6.9 inches over 8 years	2	8+
Lomatium suksdorfii	no response	5	5+