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

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Summary

Seed of *Penstemon* species is desired for rangeland restoration activities, but little cultural practice information is known for seed production of native penstemons. The seed yield response of five *Penstemon* species to three irrigation rates was evaluated over multiple years. The *Penstemon* spp. received four biweekly irrigations, applying 0, 1, or 2 inches of water (a total of 0, 4, or 8 inches of water/season). *Penstemon acuminatus, P. speciosus,* and *P. cyaneus* seed yields were maximized by 4 to 8 inches of water applied per season in warmer, drier years and did not respond to irrigation in cooler, wetter years. *Penstemon pachyphyllus* seed yields were maximized by 8 inches of water applied per season in warmer, drier years and did not respond to irrigation in cooler, wetter years. *Penstemon deustus* seed yields were not responsive to irrigation.

Introduction

Penstemon is a common wildflower genus in a wide array of plant communities in the Intermountain West from Wyoming big sagebrush to alpine areas. A number of species and developed varieties are used in horticulture and several species have been released for commercial seed production and use in wildland restoration. Cultural practices for seed production of additional species are being developed in order increase the availability of materials adapted to a greater array of environmental conditions.

The Penstemons are valuable species for adding diversity to wildland seedings. They are used to a limited extent by deer, antelope and other big game (Ogle and Peterson 2000, St. John et al. 2010, Tilley et al. 2012). The Penstemons have seen considerable use in domestic rock gardens and xeriscapes (Nold 1999). They are often included in low-maintenance landscaping in parks, recreation areas, and along roadsides where they add seasonal color.

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 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, and this could also 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 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 species of *Penstemon* native to the Intermountain West (Table 1).

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

Species	Common names
Penstemon acuminatus	Sharpleaf penstemon, sand-dune penstemon
Penstemon cyaneus	Blue penstemon
Penstemon deustus	Scabland penstemon, hotrock penstemon
Penstemon pachyphyllus	Thickleaf beardtongue
Penstemon speciosus	Royal penstemon, sagebrush penstemon

Materials and Methods

Plant establishment: *Penstemon acuminatus, P. deustus,* and *P. speciosus*

Seed of *Penstemon acuminatus, P. deustus,* and *P. speciosus* 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, the 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 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, the seed 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 0.25-inch depth.

The trial was irrigated with a minisprinkler system (R10 Turbo Rotator, Nelson Irrigation Corp., Walla Walla, WA) for even stand establishment from March 4 to April 29. 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. Seed emerged by late April. Starting June 24, the field was irrigated with the drip 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 were uneven. None of the species flowered in 2005. In early October, 2005 more seed was received from the Rocky Mountain Research Station for replanting. The empty lengths of row were replanted by hand on October 26, 2005 and fall and winter moisture was allowed to germinate the seed. In the spring of 2006, the plant stands of the replanted species were excellent, except for *P. deustus*, which was replanted on November 11, 2006 at 30 seeds/ft of row.

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 of each species. On November 17, all plots had Prowl® at 1 lb ai/acre broadcast on the soil surface for weed control. Irrigations for all species were initiated on May 19 and terminated on June 30.

Cultural practices in 2007

Penstemon acuminatus and *P. speciosus* were sprayed with Aza-Direct® at 0.0062 lb ai/acre on May 14 and 29 for lygus bug control. 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. Capture® 2EC at 0.1 lb ai/acre was sprayed on all plots of *Penstemon acuminatus* and *P. speciosus* on May 20 for lygus bug control. Irrigations for each species were initiated and terminated on different dates (Table 2). Due to substantial stand loss, all plots of *P. deustus* were disked out.

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. The flowering, irrigation timing, and harvest timing were recorded for each species (Table 2).

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

Cultural practices in 2010

The flowering, irrigation, and harvest timing of the established wildflowers were recorded for each species (Table 2). On November 17, Prowl at 1 lb ai/acre was broadcast on all plots for weed control. Due to substantial stand loss, all plots of *P. acuminatus* were disked out.

Cultural practices in 2011

The timing of flowering, irrigations, and harvests varied by species (Table 2). On November 9, Prowl at 1 lb ai/acre was broadcast on all plots for weed control.

Cultural practices in 2013

On April 3, Select Max® at 32 oz/acre was broadcast for grass weed control on all plots of *Penstemon speciosus.*

Cultural practices in 2014

On April 18, Orthene® at 8 oz/acre was broadcast to all plots of *Penstemon speciosus* for lygus bug control. On April 29, 5 lb iron (Fe)/acre was applied through the drip tape to all plots of *P. speciosus*.

Weeds were controlled in the first year after fall planting by hand weeding. In subsequent years, weeds were controlled by yearly applications of Prowl (soil active herbicide) and hand weeding. Stands of *P. speciosus* have regenerated by natural reseeding. Prowl was not applied after 2011 to encourage natural reseeding. While natural reseeding might be advantageous for maintaining stands for irrigation research, natural reseeding might be disadvantageous for seed production, because of changes in the genetic makeup of the stand over time.

Plant establishment: *Penstemon cyaneus, P. deustus,* and *P. pachyphyllus*

On November 25, 2009 seed of *Penstemon cyaneus, P. deustus,* and *P. pachyphyllus* 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.

Cultural practices in 2010

After the newly planted wildflowers had emerged, the row cover was removed in April. The irrigation treatments were not applied to these wildflowers in 2010. Stands of *Penstemon cyaneus* and *P. pachyphyllus* were not adequate for yield estimates.

Gaps in the rows were replanted by hand on November 5. The replanted seed was covered with a thin layer of a mixture of 50% sawdust and 50% hydro seeding mulch (Hydrostraw LLC, Manteno, IL) by volume. The mulch mixture was sprayed with water using a backpack sprayer.

Cultural practices in 2011

Seed from the middle 2 rows in each plot of *Penstemon deustus* was harvested with a small plot combine. Seed from the middle 2 rows in each plot of the other species was harvested manually.

Cultural practices in 2012

Many areas of the wildflower seed production were suffering from severe iron deficiency early in the spring of 2012. On April 13, 2012, 50 lb nitrogen (N)/acre, 10 lb P/acre, and 0.3 lb Fe/acre was

applied to all plots as liquid fertilizer injected through the drip tape. On April 23, 2012, 0.3 lb Fe/acre was applied to all plots as liquid fertilizer injected through the drip tape.

A substantial amount of plant death occurred in the *Penstemon deustus* plots during the winter and spring of 2011-2012, and only the undamaged parts in each plot were harvested. Seed of all species was harvested and cleaned manually. On October 26, dead *P. deustus* plants were removed and the empty row lengths were replanted by hand at 20-30 seeds/ft of row. After planting, sawdust was applied in a narrow band over the seed row. Following planting and sawdust application, the beds were covered with row cover.

Cultural practices in 2013

Seed of *Penstemon cyaneus* and *P. pachyphyllus* was harvested manually. The replanted *P. deustus* did not flower in 2013.

Weeds were controlled by hand weeding as necessary.

Cultural practices in 2014

On April 29, 0.3 lb Fe/acre was applied through the drip tape to all plots.

Seed of *Penstemon deustus* was harvested with a small plot combine. Seed of the other species was harvested manually.

Stands of *P. cyaneus* and *P. pachyphyllus* are currently poor, but might regenerate from natural reseeding. While natural reseeding might be advantageous for maintaining stands for irrigation research, natural reseeding might be disadvantageous for seed production, because of changes in the genetic makeup of the stand over time. Weeds were controlled each year by hand weeding.

Irrigation for seed production

In April, 2006 each planted strip of *Penstemon acuminatus, P. deustus,* and *P. speciosus* was divided into plots 30 ft long. Each plot contained four rows of each species. The experimental designs were randomized complete blocks 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 4 irrigations that were applied approximately every 2 weeks starting with flowering of the wildflowers. 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.

In March of 2007, the drip-irrigation system was modified to allow separate irrigation of the species due to different timings of flowering. *Penstemon deustus* and *P. speciosus* were irrigated together, but separately from *P. acuminatus*.

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.

Penstemon cyaneus, P. deustus (second planting), and *P. pachyphyllus* were irrigated together starting in 2011 using the same procedures as previously described.

Flowering, harvesting, and seed cleaning

Flowering dates for each species were recorded (Table 2). All plots produced seed in 2006, in part because they had emerged in the spring of 2005. Each year, the middle two rows of each plot were harvested when seed of each species was mature (Table 2). The plant stand for the first planting of *P. deustus* was too poor to result in reliable seed yield estimates. Replanting of *P. deustus* in the fall of 2006 did not result in adequate plant stand in the spring of 2007.

All species were harvested with a Wintersteiger small plot combine. *Penstemon deustus* seed pods were too hard to be opened in the combine; the unthreshed seed was precleaned in a small clipper seed cleaner and then seed pods were broken manually by rubbing the pods on a ribbed rubber mat. The seed was then cleaned again in the small clipper seed cleaner. The other species were threshed in the combine and the seed was further cleaned using a small clipper seed cleaner. Seed of *P. cyaneus, P. pachyphyllus,* and *P. speciosus* were harvested by hand when stands became too poor for combining.

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).

Flowering and seed set

Penstemon acuminatus and *P. speciosus* had poor seed set in 2007, partly because of a heavy lygus bug infestation that was not adequately controlled by the applied insecticides. In the Treasure Valley, the first hatch of lygus bugs occurs when 250 degree-days (52°F base) are accumulated. Data collected by an AgriMet weather station adjacent to the field indicated that the first lygus bug hatch occurred on May 14, 2006; May 1, 2007; May 18, 2008; May 19, 2009; and May 29, 2010. The average (1995-2010) lygus bug hatch date was May 18. *Penstemon acuminatus* and *P. speciosus* start flowering in early May (Table 2). The earlier lygus bug hatch in 2007 probably resulted in harmful levels of lygus bugs present during a larger part of the *Penstemon* spp. flowering period than normal. Poor seed set for *P. acuminatus* and *P. speciosus* in 2007 also was related to poor vegetative growth compared to 2006 and 2008. In 2009, all plots of *P. acuminatus* and *P. speciosus* again showed poor vegetative growth and seed set. Root rot affected all plots of *P. acuminatus* in 2009, killing all plants in two of the four plots of the wettest treatment (2 inches per irrigation). Root rot affected the wetter plots of *P. speciosus* in 2009, but the stand partially recovered due to natural reseeding.

Table 2. *Penstemon* 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
Penstemon acuminatus	2006	2-May	10-May	19-May	19-May	30-Jun	7-Jul
	2007	19-Apr		25-May	19-Apr	24-Jun	9-Jul
	2008	29-Apr		5-Jun	29-Apr	11-Jun	11-Jul
	2009	2-May		10-Jun	8-May	12-Jun	10-Jul
Penstemon cyaneus	2011	23-May	15-Jun	8-Jul	13-May	23-Jun	18-Jul
	2012	16-May	30-May	10-Jun	27-Apr	7-Jun	27-Jun
	2013	3-May	21-May	5-Jun	24-Apr	5-Jun	11-Jul
	2014	5-May	13-May	8-Jun	29-Apr	10-Jun	14-Jul
Penstemon deustus[a]	2006	10-May	19-May	30-May	19-May	30-Jun	4-Aug
	2007	5-May	25-May	25-Jun	19-Apr	24-Jun	
	2008	5-May		20-Jun			
	2011	23-May	20-Jun	14-Jul	13-May	23-Jun	16-Aug
	2012	16-May	30-May	4-Jul	27-Apr	7-Jun	7-Aug
	2013	3-May	18-May	15-Jun	24-Apr	5-Jun	
	2014	10-May	20-May	19-Jun	29-Apr	10-Jun	21-Jul
Penstemon pachyphyllus	2011	10-May	30-May	20-Jun	13-May	23-Jun	15-Jul
	2012	23-Apr	2-May	10-Jun	27-Apr	7-Jun	26-Jun
	2013	26-Apr		21-May	24-Apr	5-Jun	8-Jul
	2014	22-Apr	5-May	4-Jun	29-Apr	10-Jun	13-Jul
Penstemon speciosus	2006	10-May	19-May	30-May	19-May	30-Jun	13-Jul
	2007	5-May	25-May	25-Jun	19-Apr	24-Jun	23-Jul
	2008	5-May		20-Jun	29-Apr	11-Jun	17-Jul
	2009	14-May		20-Jun	19-May	24-Jun	10-Jul
	2010	14-May		20-Jun	12-May	22-Jun	22-Jul
	2011	25-May	30-May	30-Jun	20-May	5-Jul	29-Jul
	2012	2-May	20-May	25-Jun	2-May	13-Jun	13-Jul
	2013	2-May	10-May	20-Jun	2-May	12-Jun	11-Jul
	2014	29-Apr	13-May	9-Jun	29-Apr	10-Jun	11-Jul

[a]Second planting in the fall of 2009.

Seed yields

Penstemon acuminatus

There was no significant difference in seed yield between irrigation treatments for *P. acuminatus* in 2006 (Tables 4 and 5). Precipitation from March through June 2006 was 6.4 inches. The 64-year-average precipitation from March through June is 3.6 inches. The wet weather in 2006 could have attenuated the effects of the irrigation treatments. In 2007, seed yield showed a quadratic response to irrigation rate. Seed yields were maximized by 4.0 inches of water applied in 2007. In 2008, seed yield showed a linear response to applied water. In 2009, there was no significant difference in seed yield between treatments, but because of root rot affecting all plots in 2009, the seed yield results were compromised. By 2010, substantial lengths of row contained only dead plants. Measurements in each plot showed that plant death increased with increasing irrigation rate. The stand loss was 51.3, 63.9, and 88.5% for the 0-, 4-, and 8-inch irrigation treatments, respectively. The trial area was disked out in 2010. Following the 2005 planting, seed yields were substantial in 2006 and moderate in 2008. *P. acuminatus* performed as a short-lived perennial.

Penstemon cyaneus

Seed yields did not respond to irrigation in 2011 and 2014 (Tables 4 and 5). In 2012, seed yields increased with increasing irrigation up to the highest amount tested of 8 inches. In 2013, seed yields showed a quadratic response to irrigation with a maximum seed yield at 4 inches of water applied.

Penstemon deustus

Seed yields did not respond to irrigation in any year except 2011, when seed yields were highest with no irrigation (Tables 4 and 5).

Penstemon pachyphyllus

Seed yields did not respond to irrigation in 2011, 2012, and 2014 (Tables 4 and 5). In 2013, seed yields increased with increasing irrigation up to the highest tested amount of 8 inches.

Penstemon speciosus

In 2006-2009 seed yield of *P. speciosus* showed a quadratic response to irrigation rate (Tables 4 and 5). Seed yields were maximized by 4.3, 4.2, 5.0, and 4.3 inches of water applied in 2006, 2007, 2008, and 2009, respectively. In 2010-2012 there was no difference in seed yield between treatments. Seed yield was low in 2007 due to lygus bug damage, as discussed previously. Seed yield in 2009 was low due to stand loss from root rot. The plant stand recovered somewhat in 2010 and 2011, due in part to natural reseeding, especially in the non-irrigated plots. In 2013, seed yield increased with increasing water application, up to 8 inches, the highest amount tested. In 2014 seed yield of *P. speciosus* showed a quadratic response to irrigation rate with the calculated optimum of 276 lb/acre at 5.2 inches of irrigation water. Averaged over 9 years, seed yield was maximized by 5.0 inches of water applied.

Conclusions

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.

Due to the semi-arid environment, supplemental irrigation often may be required for successful flowering and seed set because soil water reserves may be exhausted before seed formation. The total irrigation requirements for these semi-arid-land species were low and varied by species (Table 6). *Penstemon acuminatus* and *P. deustus* did not respond to irrigation in these trials. Natural rainfall was sufficient to maximize seed production in the absence of weed competition.

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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-June	April-June	Jan-June
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.

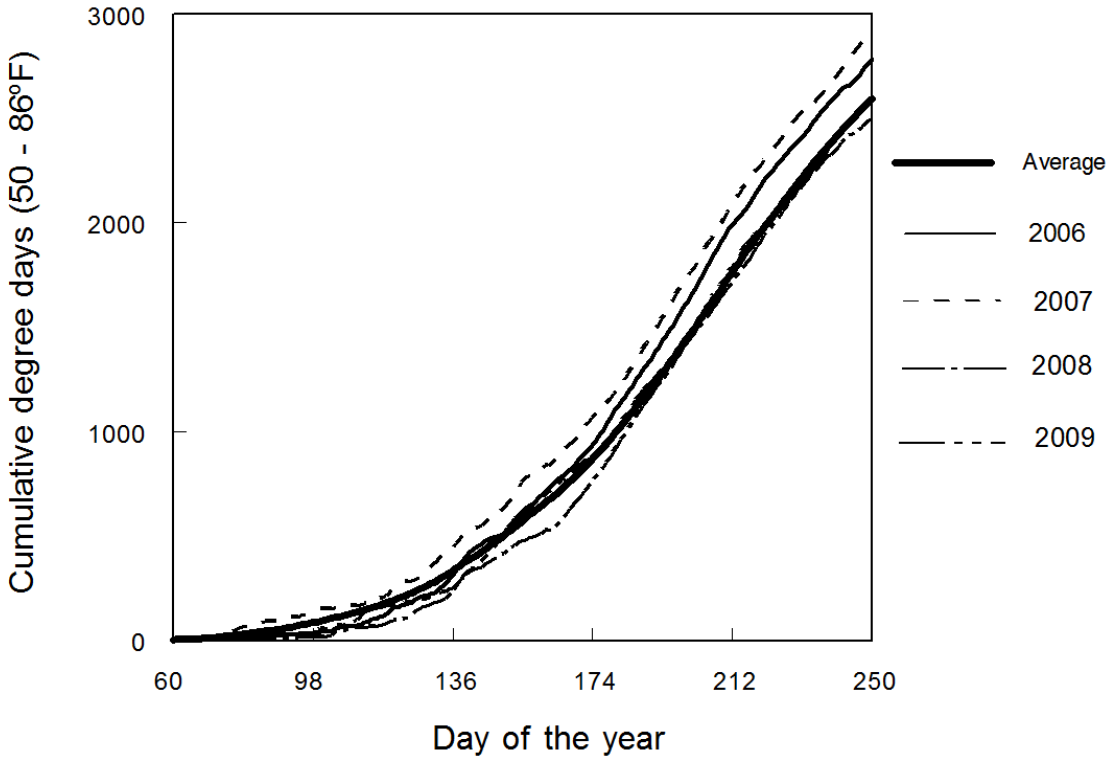

Figure 1. Growing degree-days (50-86°F) for 2006 through 2009 and 24-year average. Malheur Experiment Station, Oregon State University, Ontario, OR.

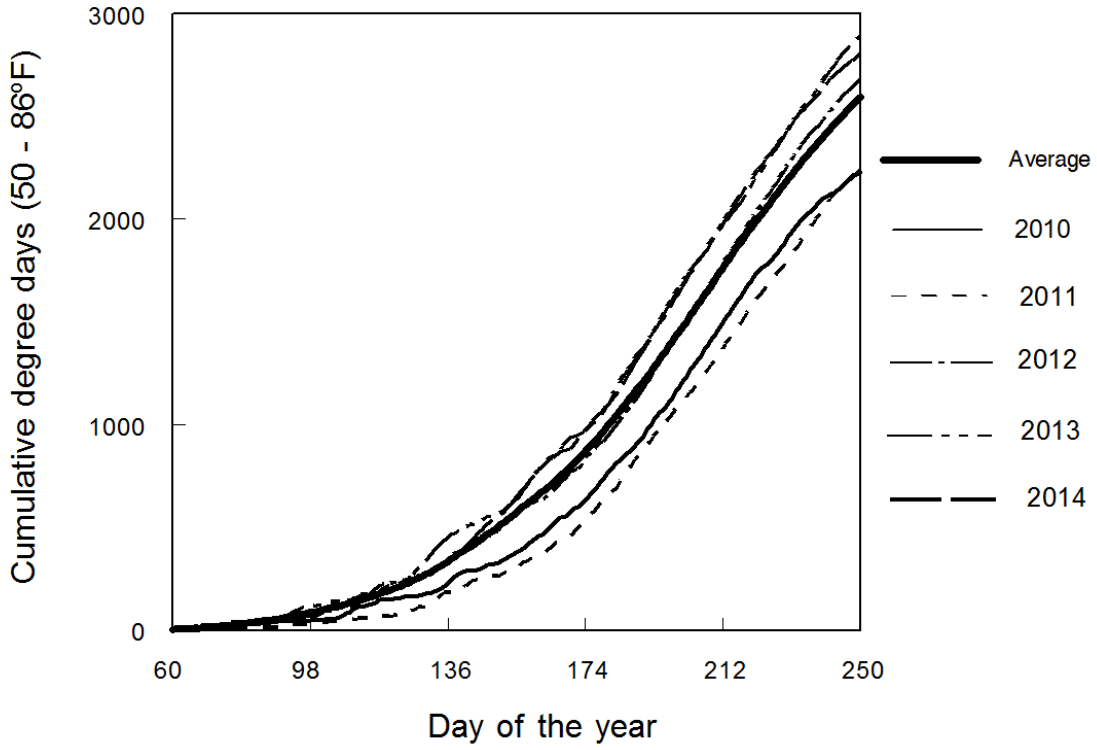

Figure 2. Growing degree-days (50-86°F) for 2010 through 2014 and 24-year average. Malheur Experiment Station, Oregon State University, Ontario, OR.

Table 4. Native wildflower seed yield response to irrigation rate (inches/season) in 2006 through 2014. Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Year	0 inches	4 inches	8 inches	LSD (0.05)
		lb/acre			
Penstemon acuminatus[a]	2006	538.4	611.1	544.0	NS
	2007	19.3	50.1	19.1	25.5[b]
	2008	56.2	150.7	187.1	79.0
	2009	20.7	12.5	11.6	NS
	2010	-- Stand disked out --			
Penstemon cyaneus	2011	857.2	821.4	909.4	NS
	2012	343.3	474.6	581.2	202.6[b]
	2013	221.7	399.4	229.2	74.4
	2014	213.9	215.4	215.1	NS
	Average	409.0	477.7	483.7	NS
Penstemon deustus[c]	2006	1246.4	1200.8	1068.6	NS
	2007	120.3	187.7	148.3	NS
	2008	-- Stand disked out --			
	2011	637.6	477.8	452.6	NS
	2012	308.7	291.8	299.7	NS
	2013	--- no flowering ---			
	2014	356.4	504.8	463.2	NS
	Average	433.7	418.3	396.0	NS
Penstemon pachyphyllus	2011	569.9	337.6	482.2	NS
	2012	280.5	215.0	253.7	NS
	2013	159.4	196.8	249.7	83.6
	2014	291.7	238.6	282.1	NS
	Average	325.4	247.0	316.9	NS
Penstemon speciosus[a]	2006	163.5	346.2	213.6	134.3
	2007	2.5	9.3	5.3	4.7[b]
	2008	94.0	367.0	276.5	179.6
	2009	6.8	16.1	9.0	6.0[b]
	2010	147.2	74.3	69.7	NS
	2011	371.1	328.2	348.6	NS
	2012	103.8	141.1	99.1	NS
	2013	8.7	80.7	138.6	63.7
	2014	76.9	265.6	215.1	76.7
	Average	108.5	174.4	152.7	36.1

[a] Planted March, 2005, areas of low stand replanted by hand in October 2005.
[b] LSD (0.10).
[c] Planted March, 2005, areas of low stand replanted by hand in October 2005 and whole area replanted in October 2006. Yields in 2006 are based on small areas with adequate stand. Yields in 2007 are based on whole area of very poor and uneven stand.

Table 5. 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.

Penstemon acuminatus						Maximum yield	Water applied for maximum yield
Year	Intercept	linear	quadratic	R^2	*P*	lb/acre	inches/season
2006	538.4	35.6	-4.4	0.03	NS[a]		
2007	19.3	15.4	-1.9	0.44	0.1	50.1	4.0
2008	56.2	30.9	-1.8	0.63	0.05	187.5	8.5
2009	19.5	-1.1		0.23	NS		
Average	165.6	17.1	-1.8	0.1	NS		
Penstemon cyaneus							
2011	836.6	6.5		0.01	NS		
2012	855.8	29.7		0.84	0.001	1093.6	8.0
2013	221.7	87.9	-10.9	0.63	0.05	399.4	4.0
2014	214.2	0.1		0.01	NS		
Average	419.5	9.3		0.17	NS		
Penstemon deustus							
2006	1260.9	-22.2		0.05	NS		
2007	120.3	30.2	-3.3	0.19	NS		
2011	615.2	-23.1		0.35	0.05	615.2	0
2012	304.6	-1.1		0.01	NS		
2014	356.4	60.8	-5.9	0.26	NS		
Average	452.7	-4.1		0.05	NS		
Penstemon pachyphyllus							
2011	507.1	-11.0		0.04	NS		
2012	263.1	-3.3		0.01	NS		
2013	156.8	11.3		0.33	0.10	247.2	8.0
2014	275.6	-1.2		0.01	NS		
Average	300.7	-1.1		0.01	NS		
Penstemon speciosus							
2006	163.5	85.1	-9.9	0.66	0.05	346.4	4.3
2007	2.5	3.2	-0.4	0.48	0.10	9.2	4.2
2008	94.1	113.7	-11.4	0.56	0.05	377.6	5.0
2009	6.8	4.4	-0.5	0.54	0.05	16.1	4.2
2010	147.2	29.8	-2.1	0.35	NS[a]		
2011	360.6	-2.8		0.01	NS		
2012	103.8	19.3	-2.5	0.30	NS		
2013	11.0	16.2		0.77	0.001	141.0	8.0
2014	76.9	77.1	-7.5	0.62	0.05	275.5	5.2
Average	108.5	27.5	-2.7	0.55	0.05	177.2	5.0

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

Table 6. Amount of irrigation water for maximum *Penstemon* 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	Year of first seed set	Life span
	inches/season	from fall planting	years
Penstemon acuminatus	0 in wetter years, 4 in warm, dry years	1	3
Penstemon cyaneus	0 in wetter years, 4 to 8 in dry years	1	3
Penstemon deustus	no response to irrigation	2	5+
Penstemon pachyphyllus	no response in 2011, 2012, and 2014, 8 inches in 2013 (dry year)	1-2	3
Penstemon speciosus	0 in cool, wet years, 4 to 8 in warm, dry years	1	3