SUBSURFACE DRIP IRRIGATION FOR NATIVE WILDFLOWER SEED PRODUCTION

Clint Shock, Erik Feibert, and Lamont Saunders
Malheur Experiment Station
Oregon State University
Ontario, OR 2007

Nancy Shaw
U.S. Forest Service
Rocky Mountain Research Station
Boise, ID

Introduction

Native forb 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 forb seed is stable and consistent seed productivity over years. 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 forbs are not competitive with crop weeds. Both sprinkler and furrow irrigation could promote seed production, but risk encouraging weeds. Furthermore, 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 of the soil surface, we hope to assure flowering and seed set without encouraging weeds or opportunistic diseases. This trial tested the effect of three irrigation intensities on the seed yield of seven native forb species.

Materials and Methods

Plant Establishment

Seed of the seven Intermountain West forb species (Table 1) was received in late November in 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 ensure germination the seed was submitted to a cold stratification treatment. The seed was soaked overnight in distilled water on January 26, 2004. After seeds were soaked, the water was drained and the seed soaked for 20 minutes in a 10 percent by volume solution of 13 percent bleach in distilled water. The water was drained and the seed placed in a thin layer in plastic containers. The plastic containers had lids with holes drilled to allow air movement. The seed 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 moist seed. In late February, seed of *Lomatium grayi* and *L. triternatum* had started sprouting.

Table 1. Forb species planted at the Malheur Experiment Station, Ontario, OR.

Species	Common name
Eriogonum umbellatum	Sulfur buckwheat
Penstemon acuminatus	Sand penstemon
Penstemon deustus	Hotrock penstemon
Penstemon speciosus	Royal or sagebrush penstemon
Lomatium dissectum	Fernleaf biscuitroot
Lomatium triternatum	Nineleaf desert parsley
Lomatium grayi	Gray's lomatium
Sphaeralcea parvifolia	Smallflower globe mallow
Sphaeralcea grossularifolia	Gooseberry leafed globe mallow
Sphaeralcea coccinea	Red globe mallow
Dalea searlsiae	Seals' prairie clover
Dalea ornata	Western prairie clover
Astragalus filipes	Basalt milkvetch

In late February, 2005, drip tape (T-Tape TSX 515-16-340) was buried at 12-inch depth between two rows (30-inch rows) of a Nyssa silt loam with a pH of 8.3 and 1.1 percent organic matter. The drip tape was buried on 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, seed of all species was planted in 30-inch rows using a custom-made plot grain drill with disk openers. All seed was planted at 20-30 seeds/ft of row. The *Eriogonum umbellatum* and the *Penstemon* spp. were planted at 0.25-inch depth and the *Lomatium* spp. at 0.5-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. *Eriogonum umbellatum*, *Lomatium triternatum*, and *L. grayi* started emerging on March 29. All other species, except *L. dissectum*, 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. Thereafter the field was not irrigated.

Plant stands for *Eriogonum umbellatum*, *Penstemon* spp., *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 blank lengths of row were replanted by hand in the *Eriogonum umbellatum* and *Penstemon* spp. plots. The *Lomatium* spp. plots had the entire row lengths replanted using the planter. The seed was replanted on October 26, 2005. In the spring of 2006, plant stand of the replanted species was excellent, except for *Penstemon deustus*.

Flowering, Harvesting, and Seed Cleaning in 2006

Eriogonum umbellatum flowering started on May 19, peaked on June 24, and ended on July 28. *Penstemon acuminatus* flowering started on May 2, peaked on May 10, and ended on May 19. *Penstemon speciosus* flowering started on May 10 and peaked on May 19. *Penstemon deustus* flowering started on May 10, and peaked on May 22.

The *Eriogonum umbellatum* and *Penstemon* spp. plots produced seed in 2006, probably because they had emerged in the spring of 2005. In these plots, only the lengths of row that had consistent stand and seed production were harvested. The plant stand for *P. deustus* was too poor to result in reliable seed yield estimates. The middle two rows of each plot were harvested using a Wintersteiger Nurserymaster small plot combine. *Penstemon acuminatus* was harvested on July 7, *P. speciosus* was harvested on July 13, E. *umbellatum* was harvested on August 3, and *P. deustus* was harvested on August 4.

Eriogonum umbellatum seeds did not separate from the flowering structures in the combine; the unthreshed seed was taken to the U.S. Forest Service Lucky Peak Nursery (Boise, ID) and run through a dewinger to separate seed. The seed was further cleaned in a small clipper seed cleaner.

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.

Penstemon acuminatus and *P. speciosus* were threshed in the combine and the seed was further cleaned using a small clipper seed cleaner.

Expansion and Fertilization of the Trials

On April 11, 2006 seed of three globe mallow species (*Sphaeralcea parvifolia, S. grossularifolia, S. coccinea),* two prairie clover species *(Dalea searlsiae, D. ornata)*, and basalt milkvetch (*Astragalus filipes*) was planted at 30 seeds/ft of row. The field was sprinkler irrigated until emergence. Emergence was poor. In late August of 2006 seed of the three globe mallow species was harvested by hand. On November 9, 2006 the six forbs were flailed. On November 10, 2006 the six forbs were replanted.

On October 27, 2006, 50 lb P/acre and 2 lb Zn/acre were injected through the drip tape to all plots of *Eriogonum umbellatum*, *Penstemon spp.*, and *Lomatium spp.* On November 11, 100 lb N/acre as urea was broadcast to all *Lomatium spp.* plots. On November 11, the *Penstemon deustus* plots were replanted at 30 seeds/ft of row. On November 17, all plots of *Eriogonum umbellatum*, *Penstemon spp.* (except *P. deustus*), and *Lomatium spp*, had Prowl® at 1 lb ai/acre broadcast on the soil surface.

Irrigation for Seed Production in 2006

In April, 2006, the field was divided into plots 30 ft long. Each plot contained 4 rows of each of *Eriogonum umbellatum, P. acuminatus, P. speciosus, P. deustus, L. dissectum, L. triternatum, and L. grayi.* The experimental design was a randomized complete block with four replicates. The 3 irrigation treatments were: a non irrigated check, 1 inch per irrigation for a total of 4.8 inches, and 2 inches per irrigation for a total of 8.7 inches. Four irrigations were applied approximately every 2 weeks starting on May 19. The amount of water applied to each plot was measured by a water meter for each plot and recorded after each irrigation (Table 3). At the first irrigation on May 19, *Penstemon acuminatus* had ended flowering, *P. deustus* and *P. speciosus* were flowering, and *Eriogonum umbellatum* was just starting flowering.

Soil volumetric water content was measured by neutron probe. The neutron probe was calibrated by taking soil samples and probe readings at 8-, 20-, and 32- inch depths during installation of the access tubes. The soil water content was determined volumetrically from the soil samples and regressed against the neutron probe readings, separately for each soil depth. The regression equations were then used to transform the neutron probe readings during the season into volumetric soil water content.

Irrigation for Seed Production in 2007

In March of 2007, the drip-irrigation system was modified to allow separate irrigation of the species due to differing growth habits. The three *Lomatium spp.* were irrigated together and *Penstemon deustus* and *P. speciosus* were irrigated together, but separately from the others. *Penstemon acuminatus* and *Eriogonum umbellatum* were irrigated individually. In early April, 2007 the three globe mallow species, two prairie clover species, and basalt milkvetch were divided into plots with a drip-irrigation system to allow the same irrigation treatments as the other forbs.

Soil volumetric water content was measured in 2007 as in 2006.

On April 5, irrigations for the three Lomatium spp. were started. On April 19, irrigations for *Penstemon deustus* and *P. speciosus* were started. On May 2, irrigations for *P. acuminatus* and *Eriogonum umbellatum* were started. Irrigation treatments were the same as in 2006. The three globe mallow species, two prairie clover species, and basalt milkvetch were irrigated together according to the treatments starting on May 16. Inadvertently, irrigation treatments were not stopped after four irrigations were applied, as in 2006. Irrigation treatments for all species were continued until the last irrigation on June 24.

Cultural Practices, Harvest, and Seed Cleaning in 2007

Penstemon acuminatus and *P. speciosus* were sprayed with Aza-Direct® at 0.0062 lb ai/acre on May 14 and May 29 for lygus bug control.

Lomatium grayi seed was hand harvested on May 30 and June 29. *Lomatium triternatum* was hand harvested on June 29 and July 16. The seed was separated from the stalks by hand and cleaned with a small clipper seed cleaner. Because the seed harvest and cleaning varied by species, the details are reported in Table 2.

The three *Sphaeralcea* species were hand harvested on June 20, July 10, and August 13. The harvested seed pods were threshed in the small plot combine with an alfalfa seed concave. The two prairie clover species were hand harvested on June 20 and July 10.

Penstemon acuminatus was harvested on July 9 with the small plot combine with an alfalfa seed concave. The seed was further cleaned with a small clipper seed cleaner. *Penstemon speciosus* was hand harvested on July 23. Hand harvest for *P. speciosus* was necessary due to poor seed set. *Penstemon speciosus* seed was separated by hand and cleaned with a small clipper seed cleaner.

Eriogonum umbellatum was harvested on July 31 using the small plot combine with a dry bean concave. The seed was threshed by hand and cleaned with a small clipper seed cleaner.

Table 2. Native forb seed harvest and cleaning by species in 2007, Malheur Experiment Station, Oregon State University, Ontario, OR.

Species	Number of harvests	Harvest method	Pre-cleaning	Threshing method	Cleaning method
Eriogonum umbellatum	1	combine[a]	none	dewinger[d]	mechanical
Penstemon acuminatus	1	combine[b]	none	combine	mechanical
Penstemon deustus	1	combine[a]	mechanical[c]	hand[e]	mechanical
Penstemon speciosus[f]	1	combine[b]	none	combine	mechanical
Lomatium dissectum	0				
Lomatium triternatum	2	hand	hand	none	mechanical
Lomatium grayi	2	hand	hand	none	mechanical
Sphaeralcea parvifolia	3	hand	none	combine	none
Sphaeralcea grossulariifolia	3	hand	none	combine	none
Sphaeralcea coccinea	3	hand	none	combine	none
Dalea searlsiae	2	hand	none	dewinger	mechanical
Dalea ornata	2	hand	none	dewinger	mechanical

[a]Dry bean concave.
[b]Alfalfa seed concave.
[c]Clipper seed cleaner.
[d]Specialized seed threshing machine at USDA Lucky Peak Nursery. In 2007, due to travel constraints, an adjustable hand-driven corn grinder was used to thresh seed.
[e]Hard seed pods were broken by rubbing against a ribbed rubber mat.
[f]Harvested by hand in 2007 due to poor seed set.

Results and Discussion

Precipitation in the fall of 2005 and spring of 2006 was higher than normal at the Malheur Experiment Station (Fig. 1). Precipitation from October 2005 through June 2006 was 15.9 inches. The 64-year average precipitation from October through June is 9.1 inches. Precipitation from March through June was 6.4 inches in 2006. The 64-year average precipitation from March through June is 3.6 inches. The wet weather could have attenuated the effects of the irrigation treatments in 2006 (Shock et al. 2007). Of the 7 species tested, only *Eriogonum umbellatum* and *Penstemon speciosus* showed seed yield responses to irrigation rate in 2006 (Table 4).

Precipitation from October 2006 through June 2007 was 6.2 inches, lower than the 64-year average. Precipitation from March through June was 2.0 inches in 2007. The total amount of water applied to the forbs was higher than planned in 2007 (Table 3). The biweekly irrigations were continued until June 24, instead of being terminated after four irrigations. The soil volumetric water content responded to the irrigation treatments (Figs. 2-6).

Emergence for the two prairie clover (*Dalea* spp.) species in the spring of 2007 was again poor. Emergence for *Penstemon deustus* and for basalt milkvetch (*Astragalus filipes*) was extremely poor; *A. filipes* produced negligible amounts of seed in 2007.

Flowering and Seed Set in 2007

Lomatium grayi started flowering in late March and ended in mid-May. *Lomatium triternatum* started flowering in mid-April and ended in early June. *Lomatium dissectum* did not flower. *Penstemon acuminatus* and *P. deustus* started flowering in early May and ended in late June. *P. speciosus* started flowering in early May and ended in late June. *Eriogonum umbellatum* started flowering in early May and ended in late July. The three *Sphaeralcea* species (globe mallow) started flowering in early May and continued flowering through September. The two *Dalea* species (prairie clover) started flowering in early May and ended in late June.

The three *Sphaeralcea* species (globe mallow) showed a long flowering period (early May through September). Multiple harvests were necessary because the seed falls out of the pods once the pods are mature.

Penstemon acuminatus and *P. speciosus* had poor seed set partly due to a heavy lygus bug infestation that was not adequately controlled by the applied insecticides. Poor seed set for *P. acuminatus* and *P. speciosus* was also related to poor vegetative growth in 2007 compared to 2006.

Seed Yields

In 2006, seed yield of *Eriogonum umbellatum* was highest with the 2-inch irrigation rate (Table 4). In 2007, seed yield of *E. umbellatum* with the 1-inch irrigation rate was significantly higher than with the nonirrigated check. Seed yield with the 2-inch rate was not significantly higher than with the 1-inch rate.

Seed yields of *Penstemon acuminatus* and *P. speciosus* in 2007 were substantially lower than in 2006, possibly due to poor vegetative growth and lygus bug damage to flowering structures (Table 4). There was no significant difference in seed yield between irrigation treatments for *P. acuminatus* in 2006. In 2007, seed yield of *P. acuminatus* was highest with the 1-inch irrigation rate. Seed yields with either the 2-inch irrigation rate or the nonirrigated check were similar and substantially lower.

For *P. speciosus* in 2006 and 2007, seed yields were increased with the 1-inch irrigation rate compared to the nonirrigated check. Seed yields with the 2-inch irrigation rate were lower, but not significantly different than for the 1-inch rate.

There was no significant difference in seed yield between irrigation treatments for *P. deustus* in 2006 and 2007. For *P. deustus*, the replanting of the low stand areas in October of 2005 and the replanting of the whole area in October 2006 resulted in very poor emergence and in plots with very low and uneven stands.

Of the three *Lomatium* species, *L. grayi* had the most vigorous vegetative growth in 2007; *L. dissectum* had the poorest vegetative growth in 2006 and 2007 and did not flower in either year. *Lomatium grayi* and *L. triternatum* showed a trend for increasing seed yield with increasing irrigation rate in 2007. The highest irrigation rate resulted in significantly higher seed yield than the nonirrigated check. The much greater *Lomatium* growth in 2007 shows promise for higher seed yields in future years.

There was no significant difference in seed yield between irrigation treatments for the three *Sphaeralcea* species, with *S. parvifolia* having the highest seed yield. The *Sphaeralcea* species seed yields ranged from 279 to 1,062 lb/acre in 2007 without irrigation.

There was no significant difference in seed yield between irrigation treatments for the two *Dalea* species, with *D. ornata* having the highest seed yield. Emergence for the two *Dalea* species was poor with plots having poor and uneven stand.

Summary and Comparison of 2006 and 2007

Precipitation from March through June was 6.4 inches in 2006 and 2.0 inches in 2007. The 64-year average precipitation from March through June is 3.6 inches.

For *Eriogonum umbellatum*, seed yield was maximized with the 2-inch irrigation rate in 2006 and with the 1- or 2-inch irrigation rate in 2007. For *Penstemon acuminatus*, seed yield was not responsive to irrigation in 2006 and was maximized with the 1-inch irrigation rate in 2007. For *P. speciosus*, seed yields were maximized with the 1-inch irrigation rate in 2006 and 2007. For *P. deustus*, seed yield was not responsive to irrigation in 2006 and 2007. None of the three *Lomatium* species flowered in 2006. *Lomatium dissectum* has been very slow to develop on the experimental site and has not flowered. Seed yield for *L. triternatum* and *L. grayi* were maximized by the highest irrigation rate of 2 inches in 2007. The three *Sphaeralcea* species and the two *Dalea* species did not respond to irrigation in 2007.

The poor emergence and resulting poor stand cast doubt on the accuracy of the seed yield response to irrigation for *Penstemon deustus*, the three *Sphaeralcea* species, and the two *Dalea* species

Conclusions

Subsurface drip irrigation systems are being 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, out of reach of stimulating weed seed germination on the soil surface and away from the plant tissues that are not adapted to a wet environment.

Knowledge about native forb seed production would help make commercial production of this seed feasible. Irrigation methods are being developed at the Oregon State University Malheur Experiment Station to help assure reliable seed production with reasonably high seed yields. Growers need to have economic return on their seed plantings, but forbs may not produce seed every year. Due to the arid environment, supplemental irrigation may be required for successful flowering and seed set many years because soil water reserves may be exhausted before seed formation. The total irrigation water requirements for these arid land species has been shown to be low, but it varied by species.

References

Shock, C.C., E.B.G. Feibert, L.D. Saunders, N. Shaw, and A. DeBolt. 2007. Seed Production of Native Forbs Shows Little Response to Irrigation in a Wet Year. Oregon State University Agricultural Experiment Station Special Report 1075:13-20.

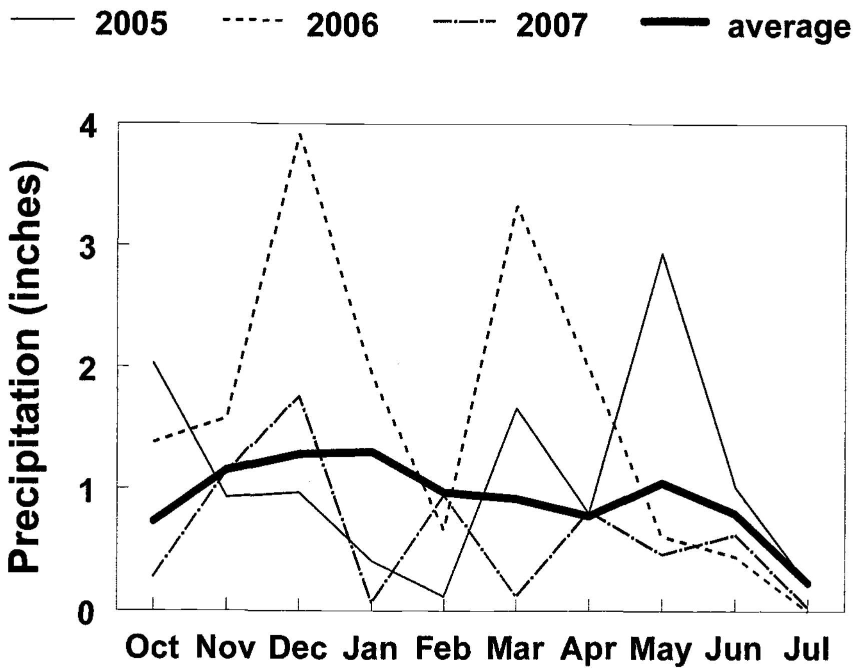

Figure 1. Monthly precipitation from October of the previous year through July for the last 3 years, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Table 3. Irrigation treatments and actual amounts of water applied to native forbs in 2006 and 2007. Precipitation from March through June was 6.4 inches in 2006 and 2.0 inches in 2007. The 64-year average is 3.6 inches. Malheur Experiment Station, Oregon State University, Ontario, OR.

Date	Irrigation rates (inches per irrigation)	Actual amount of water applied			
		Lomatium spp.	*Penstemon deustus, P. speciosus*	*Penstemon acuminatus, Eriogonum umbellatum*	*Sphaeralcea spp., Dalea spp.*
		---------- acre inches/acre ----------			
		2006			
19 May	2	2.23	2.23	2.23	
19 May	1	1.31	1.31	1.31	
2 Jun	2	2.16	2.16	2.16	
2 Jun	1	1.23	1.23	1.23	
20 Jun	2	2.04	2.04	2.04	
20 Jun	1	1.23	1.23	1.23	
30 Jun	2	2.26	2.26	2.26	
30 Jun	1	1.12	1.12	1.12	
total	2	8.69	8.69	8.69	
total	1	4.89	4.89	4.89	
		2007			
5 Apr	2	2.00			
5 Apr	1	1.28			
19 Apr	2	2.78	2.78		
19 Apr	1	1.34	1.34		
2 May	2	2.70	2.70	2.70	
2 May	1	1.40	1.40	1.40	
16 May	2	2.62	2.62	2.62	2.62
16 May	1	1.42	1.42	1.42	1.42
30 May	2	2.49	2.49	2.49	2.49
30 May	1	1.22	1.22	1.22	1.22
10 Jun	2	2.46	2.46	2.46	2.46
10 Jun	1	1.09	1.09	1.09	1.09
24 Jun	2	2.59	2.59	2.59	2.59
24 Jun	1	1.41	1.41	1.41	1.41
total	2	17.6	15.6	12.9	10.2
total	1	9.2	7.9	6.5	5.1

Table 4. Native forb seed yield response to irrigation rate (inches/irrigation) in 2006 and 2007, Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

Species	Planting date	2006				2007			
		0 inch	1 inch	2 inch	LSD(0.05)	0 inch	1 inch	2 inch	LSD(0.05)
		lb/acre							
Eriogonum umbellatum	Mar 05, Oct 05[a]	155.3	214.4	371.6	92.9	79.6	164.8	193.8	79.8
Penstemon acuminatus	Mar 05, Oct 05[a]	538.4	611.1	544	NS	19.3	50.1	19.1	25.5[f]
Penstemon deustus	Mar 05, Oct 05[b]	1246.4	1200.8	1068.6	NS	120.3	187.7	148.3	NS
Penstemon speciosus	Mar 05, Oct 05[a]	163.5	346.2	213.6	134.3	2.5	9.3	5.3	4.7[f]
Lomatium dissectum	October 05[c]	---- no flowering ----				---- no flowering ----			
Lomatium triternatum	October 05[c]	---- no flowering ----				2.3	17.5	26.7	16.9[f]
Lomatium grayi	October 05[c]	---- no flowering ----				36.1	88.3	131.9	77.7[f]
Sphaeralcea parvifolia	November 06[d]					1062.6	850.7	957.9	NS
Sphaeralcea grossularifolia	November 06[d]					442.6	324.8	351.9	NS
Sphaeralcea coccinea	November 06[d]					279.8	262.1	310.3	NS
Dalea searlsiae[e]	November 06[d]					11.5	10.2	16.4	NS
Dalea ornata[e]	November 06[d]					47.4	27.3	55.6	NS

[a]Areas of low stand replanted by hand in October 2005.
[b]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.
[c]Whole area replanted in October 2005.
[d]Whole area replanted in November 2006.
[e]Poor and uneven stand.
[f] LSD (0.10).

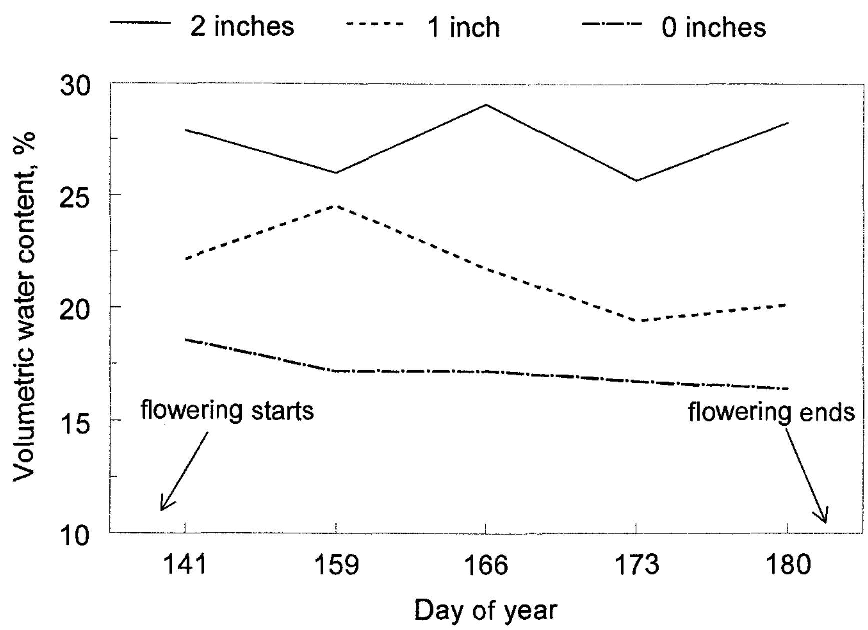

Figure 2. Soil volumetric water content for *Eriogonum umbellatum* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. *E. umbellatum* was harvested on July 31 (day 212). Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

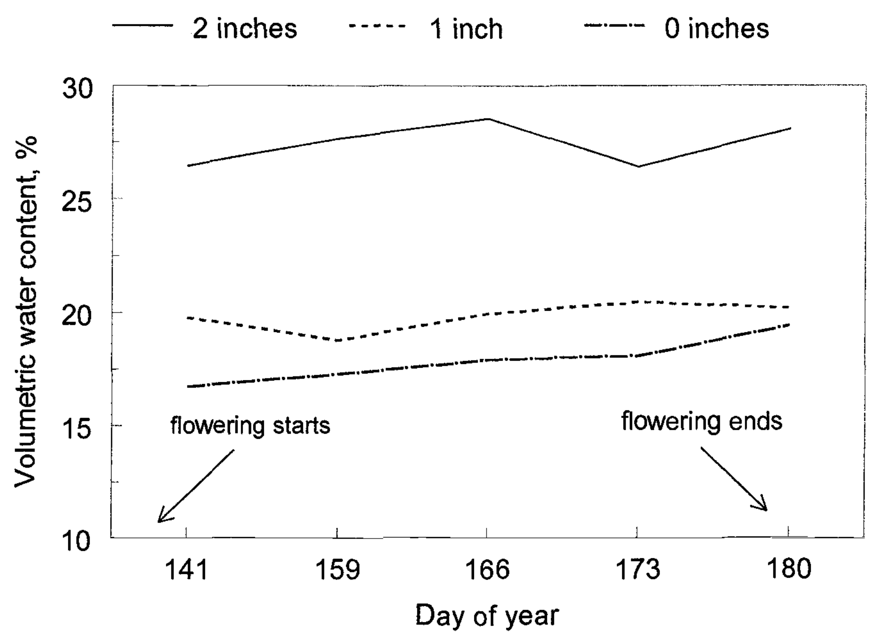

Figure 3. Soil volumetric water content for *Penstemon acuminatus* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

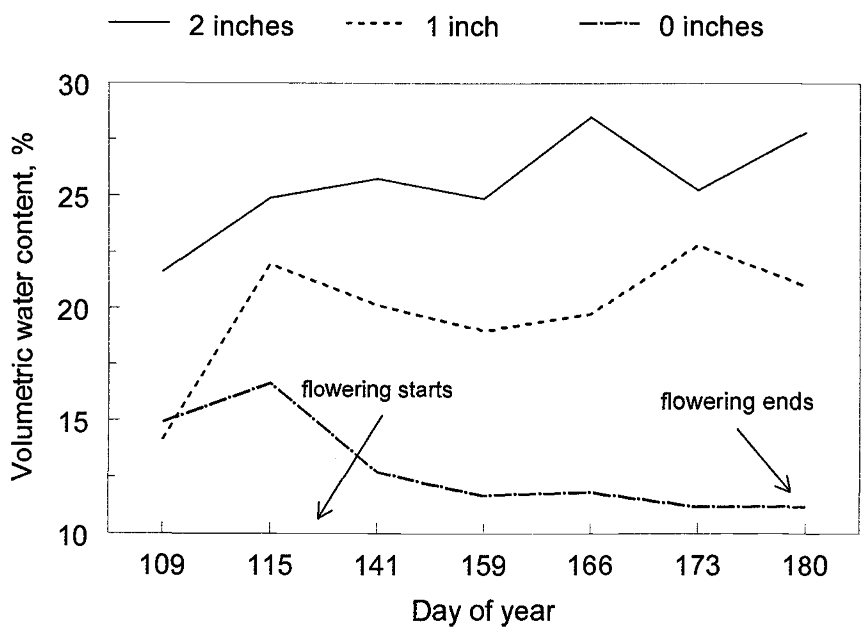

Figure 4. Soil volumetric water content for *Penstemon speciosus* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. *P. speciosus* was harvested on July 23 (day 204). Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

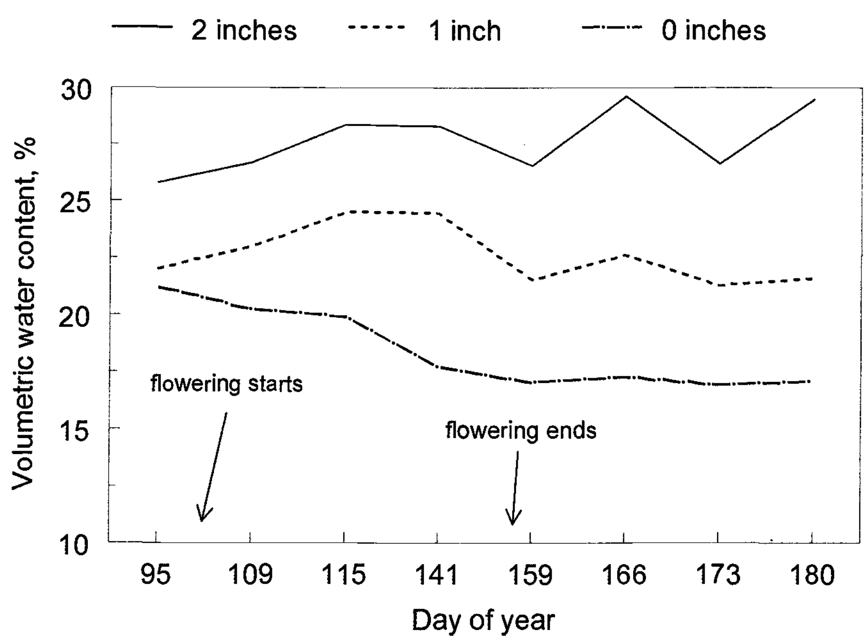

Figure 5. Soil volumetric water content for *Lomatium triternatum* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. *L. triternatum* was harvested on June 29 (day 180) and July 16 (day 197). Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.

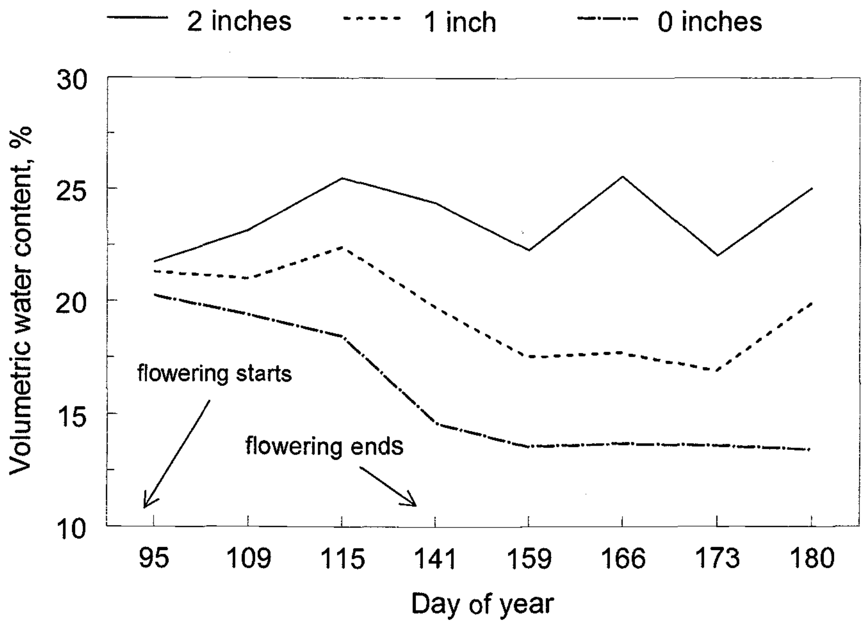

Figure 6. Soil volumetric water content for *Lomatium grayi* over time. Soil volumetric water content is the combined average at the 8-, 20-, and 32-inch depths. *L. grayi* was harvested on May 30 (day 151) and June 29 (day 180). Malheur Experiment Station, Oregon State University, Ontario, OR, 2007.