Report of the Intermountain Native Plants Cooperative

Volume 4 *December 2012*

An annual report of research and extension activities for members of WERA-1013, Intermountain Regional Evaluation and Introduction of Native Plants

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Forward

The Intermountain Native Plants Cooperative, initiated in 2007, is a group of researchers who share an interest in utilizing native plants in arid urban landscapes, sharing research-based information, and exchanging superior germplasm. All are members of WERA-1013, Intermountain Regional Evaluation and Introduction of Native Plants, an officially recognized Western Education/Extension and Research Activity. The Report of the Intermountain Native Plants Cooperative is published annually and contains announcements of studies in progress by members and updates of germplasm evaluations. Some of the various research reports include work on such diverse topics as the selection criteria of native plants for urban landscapes, sexual and asexual propagation techniques of unique plants, native plant breeding techniques, native plant genetic diversity studies, evaluations on weediness of native plants in the urban landscapes and many other native plant related studies.

Cover: The photo on the cover was taken by Heidi Kratsch and is of baby blue eyes, an annual plant of the species *Nemophila menziesii* native to Oregon, California, and Nevada.

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Announcements

2014 American Penstemon Society Annual Meeting is slated to be held in Springdale, Utah, May 16-18, 2014. For details visit http://apsdev.org/aps/meetings.html

2013 The Eriogonum Society Annual Meeting will be out of Farmington, New Mexico, September 19-22, 2013. For details visit http://www.eriogonum.org/

2013 WERA Meeting will be hosted by Heidi Kratsch in Reno, NV, October 11-12, 2013.

2014 The Eriogonum Society Annual Meeting will be out of Twin Falls, Idaho, during the 3rd week of June, 2014 (final dates still to be determined). For details visit http://www.eriogonum.org/

Commercializing production of Montana native plants

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Part I – Evaluation of Native Ornamental Perennials

"Built Landscape" is defined as features and patterns reflecting human occupation and use of natural resources. Many arguments have been put forth for including native plants in the built landscape and for using them on disturbed sites. Native plants are adapted to our soils and climate; require less care, irrigation water, fertilizer, and disease control, all leading to: reduced energy consumption and pollution; preservation of germplasm and genetic resources; restoration of soil and microbial activity; erosion control; sources of food and habitat for native wildlife; reduction in competition from non-native and invasive species; reduction of landscape plant invasiveness; refuges for native pollinators; plus they give us both a sense of place and a feeling of stewardship toward our natural heritage (NPS 2010, ABNATIVE 2010, FS 2010). For many of these reasons, recent surveys show an increased consumer preference for native plants in the landscape (Helfand et al. 2006, Larsen and Harlan 2006), as well as an increased demand by landscape architects to design for difficult or unique site conditions (Brzuszek et al. 2007). Demand for native plants is reaching a critical stage for commercial growers and landscapers in Montana (Zadegan et al. 2008).

However, several "kinks in the pipeline" hinder the ability of local industry to meet rising demand. First, landscaping and restoration, by definition, involve putting native plants into non-native or disturbed soils and greatly altered environmental conditions. Native plants are not necessarily suited to a new landscape where water, soil, temperature, nutrient, and light conditions vary widely from their established habitats. We simply do not know the limitations and tolerances of native plants to the landscape outside of their native range.

Second, rapid production of native plants in a commercially viable setting is often difficult due to a lack of knowledge about growth of these plants. Commercial growers do not have the capacity or knowledge to meet the rising demand for native plants.

Third, the general public, as well as landscape design and architectural professionals, have limited knowledge concerning native plants, their appropriate use, and their ornamental characteristics. Often, landscape designers and architects do not use native plant materials even when easily accessible in the garden marketplace because the industry is lacking an appropriate guide to plant selection. There is not enough available information regarding how Montana natives might solve landscaping problems and provide specific effects associated with texture, color, and form.

Montana State University at Bozeman has initiated research to evaluate and describe native plants that may be suitable for landscape use. Twelve planting beds were constructed at the MSU Horticulture Farm (Fig. 1). Three beds each are drip irrigated at each of four levels (0, ¼, ½, and full supplementation). The experiment is set up in a randomized split-plot design with species randomized within each irrigation level. The beds are planted with Montana native perennials, initially starting with 9 to 12 plant species for which greenhouse and propagation protocols have been established.

Fig. 1. Layout of the 12 planting beds for the Native Ornamental Perennial water experiment at the MSU Horticulture Farm. Each long column is a single water level. Each species is randomly

Priority for species in the planting beds is given to those not yet established in the landscape industry. The beds were made large enough so as to add species in future years as greenhouse propagation experiments are completed (see Table 1 for a species list). Suggestions for additional species are being compiled with advice from native plant growers. Transplants are derived from greenhouse starts produced by the researchers and from local native plant producers. Most recently, transplants were acquired from Idaho State University, Ag Experiment Station at Aberdeen, ID. Depending on plant availability and plant size, at least three plants are placed within each plot. Plants are observed and measured weekly throughout the summer and notes taken on plant size, bloom number and size, and plant survival. Subsequent to establishment, winter injury is monitored. Observation and maintenance of the plants is done in conjunction with the MSU Master Gardener program to aid in educating the public regarding native plants in the landscape.

Table 1. List of native plant species established in the native ornamental perennial water experiment at the MSU Horticulture Farm.

Species established in 2010	**Species established in 2012**
Achillea millefolium	*Acnatherum hymenoides*
Anemone multifida	*Anemone multifida*
Anemone patens	*Anemone patens*
Arnica cordifolia	*Arnica cordifolia*
Besseya wyomingensis	*Balsamorhiza sagittata*
Campanula rotundifolia	*Besseya wyomingensis*
Dalea candida	*Campanula rotundifolia*
Echinacea angustifolia	*Echinacea angustifolia*
Elymus canadensis	*Echinacea pallida*
Eriogonum umbellatum	*Eriogonum compositum*
Festuca idahoensis	*Eriogonum heracleoides*
Gaillardia aristata	*Eriogonum umbellatum*
Geranium viscosissimum	*Geranium viscosissimum*
Geum triflorum	*Geum rosii*
Heterotheca villosa	*Geum triflorum*
Heuchera parvifolia	*Heterotheca villosa*
Iliamna rivularis	*Heuchera parvifolia*
Leymus cinereus	*Hymenoxys acaulis*
Lupinus argenteus	*Iliamna rivularis*
Monarda fistulosa	*Leymus cinereus*
Penstemon albertinus	*Monarda fistulosa*

Penstemon nitidus	*Monarda methaefolia*
Phacelia hastata	*Penstemon albertinus*
Ratibida columnifera	*Penstemon barbatus*
Rudbeckia hirta	*Penstemon confertus*
Schizachyrium scoparium	*Penstemon gracilis*
Sedum stenopetalum	*Penstemon nitidus*
	Phacelia hastata
	Poa secunda
	Rudbeckia hirta
	Sedum stenopetalum

Part II – Evaluating Native and Adapted Fine Fescues for Turfgrass Applications

Evaluation is continuing on native fine fescue plots designed to determine the effect of mowing height on quality, survivability, and longevity. Thirteen native fescue species and mixes were seeded in individual plots 90' x 5' in the fall and watered at 1" per week through the remaining fall period. The following spring plots were watered evenly with 0.5 inches of water per week. Subplots (3.5' wide), perpendicularly intersecting the species plots, were left unmowed (nm) or were mowed at one of three heights: 0.5" (low), 1.5" (medium), or 3" (high) (see Table 2).

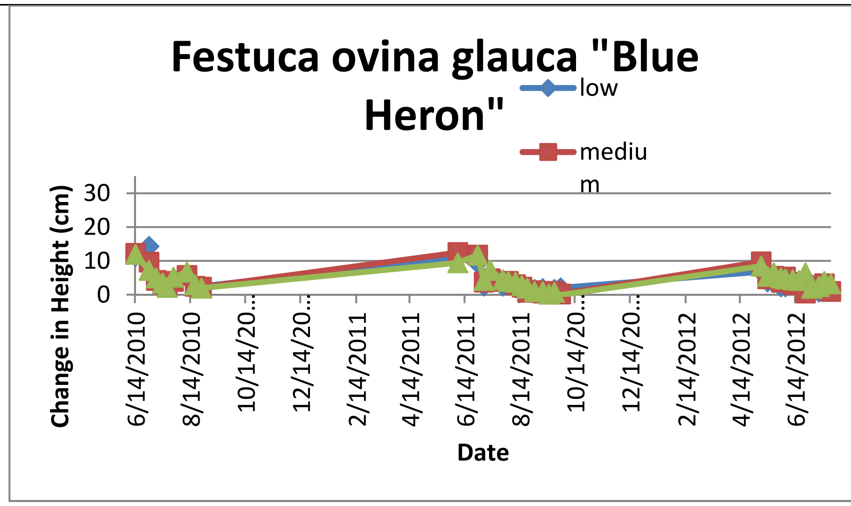
Table 2. Layout of the native and adapted fine fescue mowing height experiment. Two replicates are shown. The experiment includes 4 replicates of each mowing height.

Species / Mowing Height	**nm**	**med**	**low**	**high**	**low**	**med**	**high**	**nm**
Festuca arizonica 'Redondo'								
Festuca ovina glauca 'Blue Heron'								
Festuca trachyphylla 'Berkshire'								
Festuca trachyphylla 'Rescue 911'								

Festuca trachyphylla 'Aurora Gold'								
Festuca idahoensis 'Nezpurs'								
Festuca ovina duriscola 'Durar'								
Festuca rubra 'Florentine'								
Festuca rubra commutata 'Tiffany'								
Festuca ovina 'Covar'								
Festuca rubra 'Molate' + Festuca ovina 'Covar'								
Festuca rubra 'Molate'								
Festuca ovina 'Black Sheep' + 'Covar' + Festuca ovina duriscola 'Big Horn'								

Experimental measurements on the plots include growth response as determined by height of regrowth prior to mowing, visual quality as determined by a rating scale of 1 (dormant) to 9 (highest quality), species survival, and species composition for mixes (see Fig. 2). In the second season after establishment, a survey of client preference will be conducted with undergraduate students, master gardeners, and public tour groups. This survey will address the preferences for the species and the mowing height of the fine fescues.

Fig. 2. Pictures and growth graphs for the 9 fine fescue species established in this study as monocultures. Each picture is an unmowed plot in the foreground with plots of various mowing heights in the mid-section and another unmowed plot in the background. Color varied greatly for each species tested. Seasonal browning during dry periods occurred at different stages for each species, but at similar stages for all mowing heights within a species. For most of the species, the grasses had the same change in height (growth) regardless of mowing height. In the climate of Montana, the theoretical fall growth peak for these cool-season species did not occur before the weather turned cold and irrigation was turned off (late September/early October).

<table>
<tr><td>Picture of the grass species</td><td>Growth Response</td></tr>
<tr><td></td><td>
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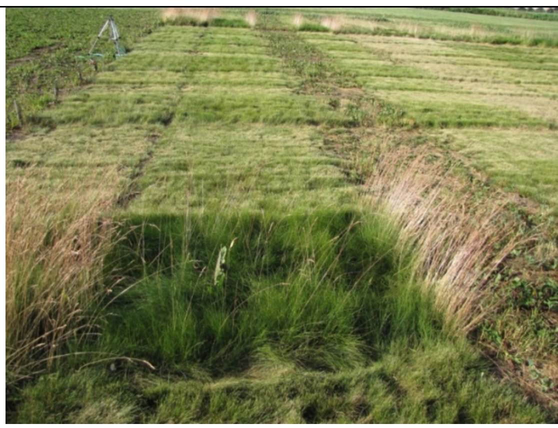
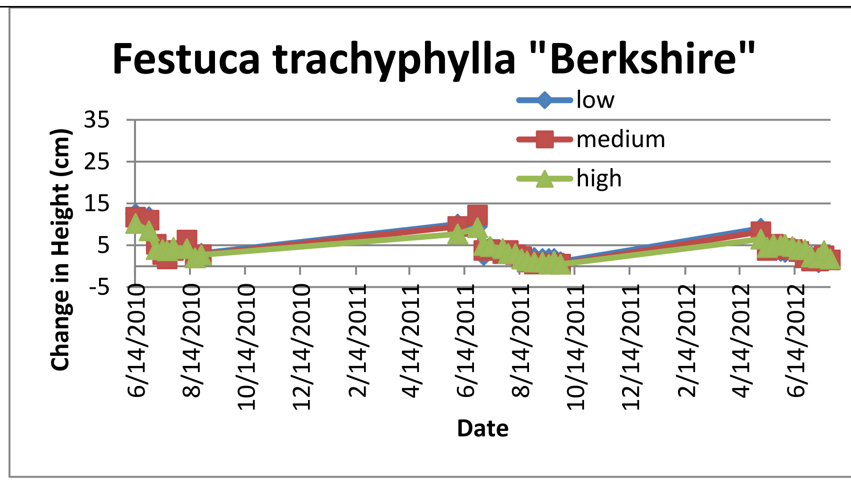
<tr><td></td><td>
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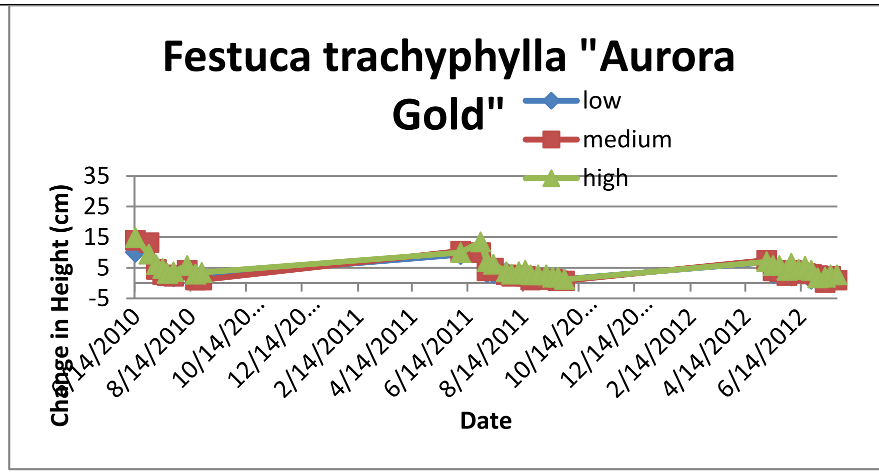
Festuca trachyphylla "Aurora Gold"
low
medium
high
Change in Height (cm)
35
25
15
5
-5
6/14/2010
8/14/2010
10/14/20…
12/14/20…
2/14/2011
4/14/2011
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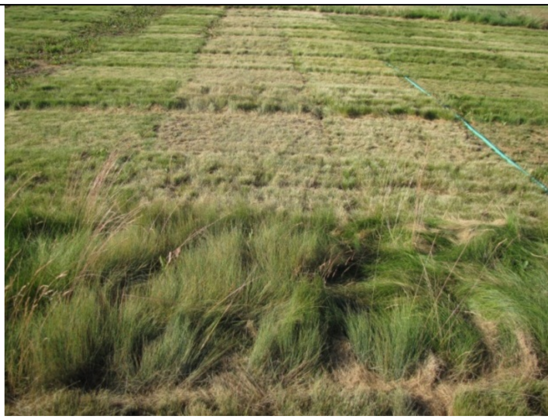
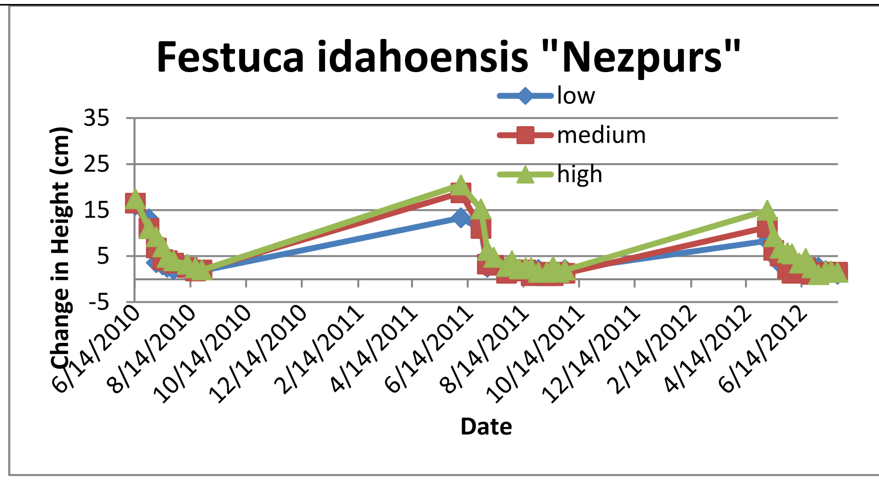
12/14/20…
2/14/2012
4/14/2012
6/14/2012
Date




Festuca idahoensis "Nezpurs"
low
medium
high
Change in Height (cm)
35
25
15
5
-5
6/14/2010
8/14/2010
10/14/2010
12/14/2010
2/14/2011
4/14/2011
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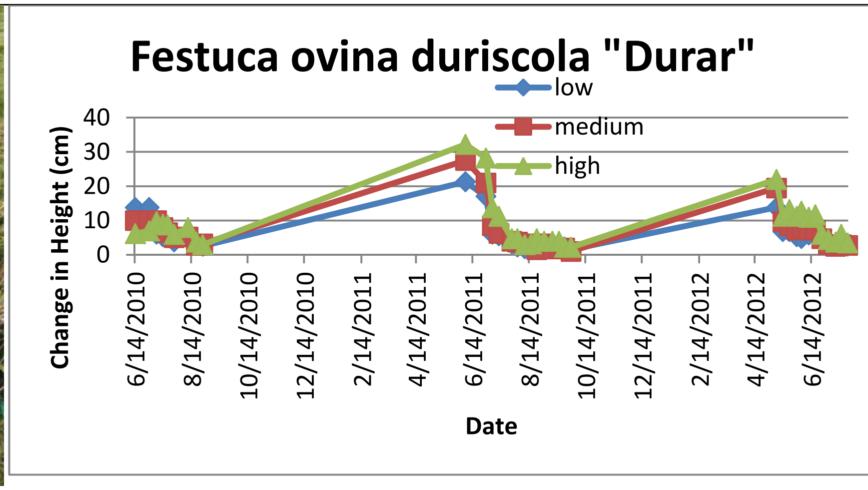
4/14/2012
6/14/2012
Date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low
medium
high
Change in Height (cm)
0
10
20
30
40
6/14/2010
8/14/2010
10/14/2010
12/14/2010
2/14/2011
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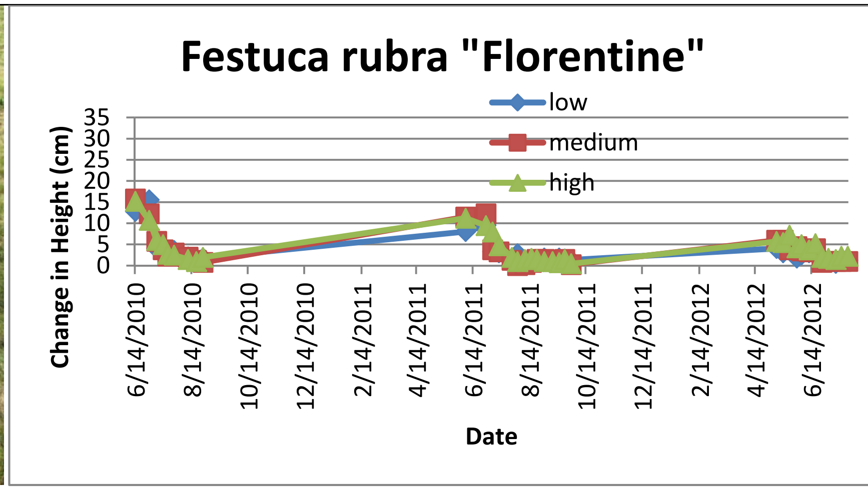
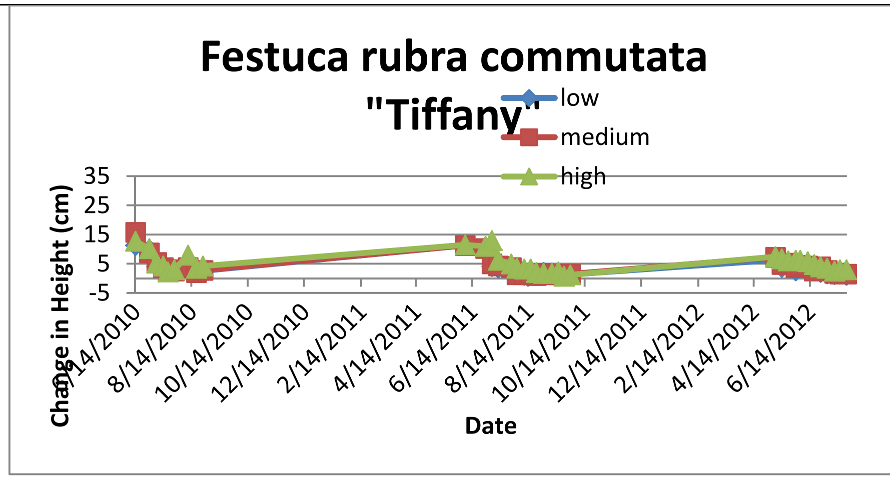
4/14/2012
6/14/2012
Date


Festuca rubra "Florentine"
low
medium
high
Change in Height (cm)
0
5
10
15
20
25
30
35
6/14/2010
8/14/2010
10/14/2010
12/14/2010
2/14/2011
4/14/2011
6/14/2011
8/14/2011
10/14/2011
12/14/2011
2/14/2012
4/14/2012
6/14/2012
Date


Festuca rubra commutata "Tiffany"
low
medium
high
Change in Height (cm)
35
25
15
5
-5
6/14/2010
8/14/2010
10/14/2010
12/14/2010
2/14/2011
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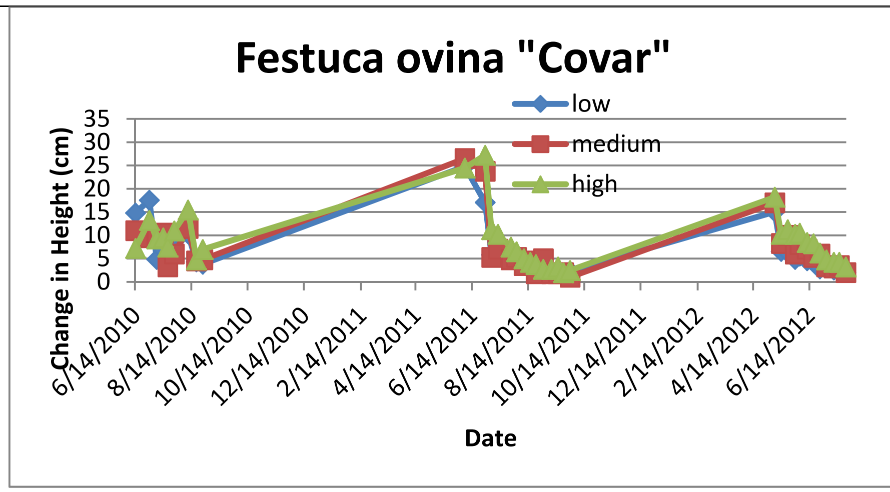
4/14/2012
6/14/2012
Date


Festuca ovina "Covar"
low
medium
high
Change in Height (cm)
35
30
25
20
15
10
5
0
6/14/2010
8/14/2010
10/14/2010
12/14/2010
2/14/2011
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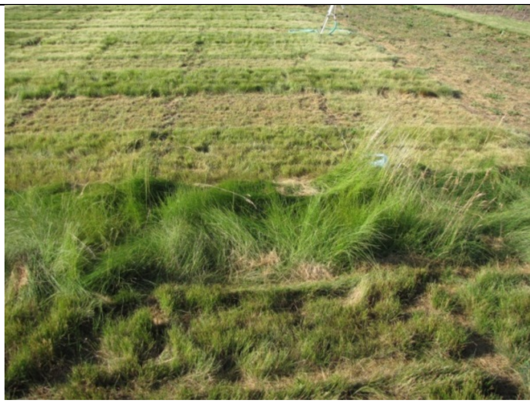
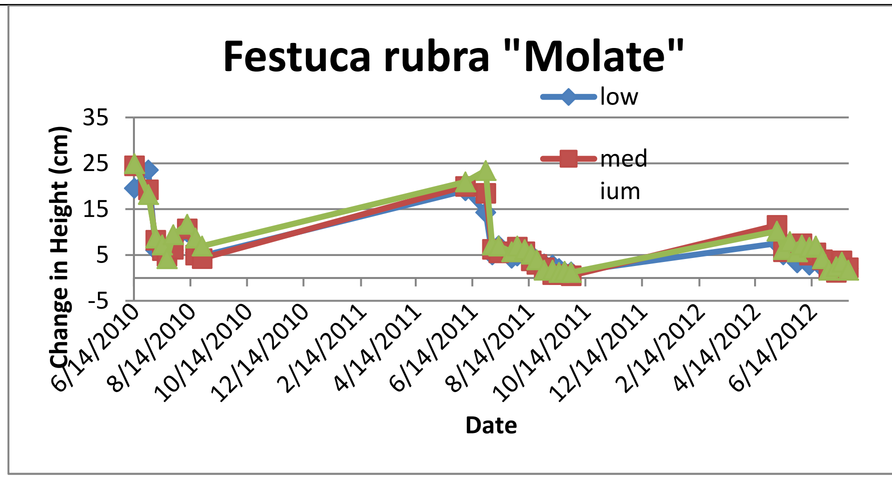
4/14/2012
6/14/2012
Date





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Annual flowers have a place in native plant nurseries and landscapes

Heidi Kratsch

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Introduction

Annual flowers make up one of the most valuable aspects of retail nursery/garden center business because they provide instant color for the customer. A common problem cited by retailers of native plants is that many don't look their best at the time of sale, which makes them less desirable to the consumer. This has limited the market, in many cases, to customers already familiar with native plant characteristics.

Some nurseries strive to overcome this problem by installing on-site demonstration gardens, or by including a tag with a picture of the plant in bloom. Another strategy they might consider is to include native annual flowers in their inventory, to provide color early in the season and expand their market to customers unfamiliar with native plants.

Annual native flowers serve valuable purposes in native plant landscaping. In addition to providing quick and reliable color, many will re-seed and return year after year. This provides a naturalized look to a garden space and enhances the "native feel" of the landscape. Native annuals may also be valuable in regions prone to wildfires. They can be used within the defensible space zone (within 30 feet of the home) because they have a high moisture content when actively growing, and die back to the ground at the end of the season, when wildfire risk is greatest.

Methods

We are investigating the nursery production and landscape value of five native annual species, *Clarkia bottae* (Onagraceae), *Collinsia heterophylla* (Scrophulariaceae), *Gilia tricolor* (Polemoniaceae), *Nemophila menziesii* (Hydrophyllaceae) and *Phacelia campanularia* (Hydrophyllaceae). Plants were purchased as seed from the Theodore Payne Foundation in Sun Valley, California. They were germinated by direct-seeding into standard peat-based potting mix in 1.5-inch by 8-inch Cone-tainers™, and kept moist using a greenhouse mist bench. Half the seeds of each species were cold-, moist-stratified for two weeks prior to seeding into containers.

Plant Characteristics

Clarkia bottae (Botta's Clarkia)
Height: 9 to 18 inches
Spacing: 12 to 15 inches
Flowers: Bowl-shaped flowers with pink to lavender pleated petals, occurring on spindly, waxy stems in leaf axils; blooms April to July.
Light: Full sun to part shade
Soil: Tolerates clay, salinity, alkalinity
Natural Habitat: Open areas in chaparral, woodland and coastal shrub communities in California.
Landscape Use: Good for flower borders, containers, naturalized meadows; may re-seed but not reliably.

Germination: No pre-treatment needed; sow just below soil surface.
Flower induction: Unknown

Collinsia heterophylla (Purple Chinese Houses)
Height: 1 to 2 feet
Spacing: 18 to 24 inches
Flowers: Snapdragon-like, purple and white, occurring on spires above foliage; blooms March to June.
Light: Full sun to part shade
Soil: Prefers rich, moist soil.
Natural Habitat: Shady places in chaparral, open mixed woodland and oak woodland communities in California.
Landscape Use: In flower borders, shady spots, butterfly gardens, groundcover for bulbs; also good as a cut flower; will re-seed.
Germination: Requires light; press lightly on top of soil; no pre-treatment needed.
Flower induction: Facultative long-day plant; irradiation-indifferent.

Gilia tricolor (Bird's-Eye Gilia)
Height: 1 to 2 feet
Spacing: 12 to 18 inches
Flowers: 5-petaled, trumpet-shaped in clusters held above fernlike foliage, pale violet blooms with deep purple throat and yellow base; light blue stamens; chocolate scent; attractive to hummingbirds; blooms March to July.
Light: Full sun to part shade
Soil: Adaptable
Natural Habitat: Open grasslands, hills and valleys in California.
Landscape Use: In flower gardens, borders, dried flower arrangements; will re-seed.
Germination: Sow on top of soil; no pre-treatment needed.
Flower induction: Unknown

Nemophila menziesii (Baby Blue Eyes)
Height: 4 to 12 inches
Spacing: 9 to 12 inches
Flowers: Bright blue, bowl-shaped with black-dotted white centers on succulent stems; blooms February to June.
Light: Full sun to part shade.
Soil: Sandy to loamy.
Natural Habitat: Meadows, grasslands, chaparral, woodlands, slopes and desert washes in California, rarely above 5,000 feet.
Landscape Use: Xeric gardens; will re-seed.
Germination: Winter annual; germination inhibited by high temperatures and light.
Flower induction: Day-neutral plant; irradiation-indifferent; 65 to 75 degrees F.

Phacelia campanularia (Desert Bells)
Height: 6 to 18 inches
Spacing: 9 to 12 inches
Flowers: Bright blue with protruding yellow anthers, bell-shaped with white at the base of the throat, occurring alongside softly hairy, heart-shaped leaves; blooms February to June.
Light: Full sun to part shade
Soil: Gritty, fast-draining
Natural Habitat: Open, sandy or gravelly areas to pinyon-juniper woodlands in California and Arizona, rarely above 5,000 feet.

Landscape Use: Xeric gardens, borders, containers; will re-seed.
Germination: Winter annual; germination inhibited by high temperatures and light.
Flower induction: Day-neutral; irradiation-indifferent.

Conclusions

Annual flowers are easy to grow, and seeds require little pre-treatment. They can be sold by retail nurseries as seed or as plants, where they can be used to boost sales of native species by providing a splash of color to native plant displays. The challenge is to define the conditions under which bloom can be induced. We have grown the above five species and recorded the conditions under which they germinate optimally. Further work will refine our knowledge of induction of bloom and better define their landscape tolerance in the Great Basin region.

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Wild buckwheats (*Eriogonum* spp.) with potential for incorporation into water-conserving landscapes

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Introduction:

The genus *Eriogonum*, known commonly as wild buckwheats, includes approximately 250 species of sub-shrubs, herbaceous perennials, and annuals. Many of these species have very attractive foliage, beautiful flowers, and long bloom periods, making them ideal candidates for landscape specimens in water-conserving gardens. To date, few of these species have been exploited for commercial purposes, though the potential is evident. Superior species of *Eriogonum* for landscape use are found in two subgenera, *Eucycla* and *Oligogonum*. Plants found in these two subgenera are typically perennial and have persistent leaves and attractive flowers.

University of Idaho personnel located at the Aberdeen R & E Center initiated a native plant domestication project in 2005. Acquisition and evaluation of wild buckwheats has been a priority from the commencement of the project. To date, 310 accessions of *Eriogonum*, representing 48 species, have been evaluated in common garden plot located at the R & E Center. Thirty-five of the accessions have been found to exhibit outstanding horticultural characteristics and 17 of these accessions have been transferred to a partnering native plant nursery called “Native Roots” for the purpose of commercial exploitation.

Many of the buckwheat species evaluated in the native plant domestication project have proven to have excellent characteristic for use as landscape specimens. The objective of this paper is to describe the traits of some horticulturally superior *Eriogonum* species and accessions as documented in common garden evaluation trials.

Evaluation Procedures:

The University of Idaho native plant domestication project involves acquisition, establishment, evaluation, and selection of Intermountain West species, including the wild buckwheats. This is an exploratory activity involving procedures that maximize the number of accessions evaluated at the expense of in-depth testing. One strategy used to maximize numbers is to utilize unreplicated common gardens for evaluation and selection purposes, similar in concept to crop breeding strategies employed to evaluate early generation germplasm.

Eriogonum species in common garden evaluations at the Aberdeen R & E Center

Establishment of *Eriogonum* accessions into a common garden and subsequent evaluations, follow a well-established set of procedures. The first step is to stratify seed for 3 to 4 weeks at 40°F. Vernalized seed is then planted into into flats. When the seedlings develop sufficiently to have 3 to 4 true leaves they are teased out of the flats and transplanted into individual pots. This process is designed to mimic common nursery handling procedures and to eliminate accessions that do not survive the handling process.

In late May the plants are transplanted into the field. Newly transplanted accessions are irrigated regularly for the first 6 to 8 weeks (0.25 to 0.5 inches of water applied every other day for the first two weeks, 1 inch applied once a week until establishment is complete) . Late in the first season and in subsequent years, the irrigation applications are reduced significantly to a level equivalent to approximately 30% of turfgrass ET. Minimal or no artificial selection pressure is applied during the summer of establishment. The first winter provides natural selection for hardiness and adaptation. Beginning the second spring after establishment, the plants are evaluated for vigor, plant aesthetics, flower color, bloom period, plant size, pest response, and other important horticultural traits. Negative selection pressure procedures are employed. Inferior accessions and plants within accessions are eliminated. Superior plants within accessions are selected for seed harvest. The seed is used to initiate additional cycles of selection, or relatively stable selections are established in seed increase blocks.

These blocks serve to produce breeder seed which can be used for material transfer to the "Native Roots" industry partner.

The selection conditions are designed to give preference to plants that can withstand a zone 4 climate, limited water availability, and calcereous soils. These selection conditions should result in plants that can survive and thrive in water-conserving landscapes throughout much of the Intermountain West.

Here are descriptions of some of the best performing species/accessions of wild buckwheats included in the trials to date:

Subgenus Eucycla

Eriogonum brevicaule var. ***bannockense*** (Shortstem Buckwheat): The var. *bannockense* is one of the more attractive forms of this species, but all forms are worthy of cultivation. Native range includes southeastern Idaho, western Wyoming, northwestern Utah, and northern Nevada. One remarkable trait of this species is an exceptionally long bloom period, beginning in May and lasting well into October. The felt-like, deciduous, silver-gray leaves form a loose mound that grows a diameter of one foot across and 8 inches tall. Dark yellow pom-pom flowers grow at the top of slender stalks, rising six to eight inches above the foliage.

Eriogonum brevicaule var. *bannockense*

Eriogonum corymbosum (Lacy Buckwheat): This species is divided into several confusing botanical varieties, each with significant variability within itself. Southwestern Wyoming, eastern Utah, western Colorado, and northern Arizona make up the primary region of origin. The best forms of this species make remarkable specimen plants in a dry garden with their dense, precisely semi-hemispherical shape. The deciduous leaves are cauline, not showy, and unimportant to the visual impact of the plant. The wiry stems of the inflorescence intertwine to create a rounded, cage-like appearance. The tiny white or pink flowers are numerous and distributed evenly across the entire plant. The slow seasonal development and late bloom time (August into November) put this species at its best in fall.

Eriogonum corymbosum

Eriogonum niveum (Snowy Buckwheat): This species is found along the border region between Idaho and the east edges of Oregon and Washington. Although herbaceous, with deciduous leaves, plants of this species become quite large during the summer and take a distinctly shrubby form. The fuzzy, silvery leaves form a basal mound approximately 8 inches tall, but also appear on the flower stalks, almost into the inflorescence. The numerous bright white flowers are scattered across the plant, arranged in small clusters rather than distinct heads. The bloom is late, August into October, thereby contributing late-season value to a dry garden.

Eriogonum niveum
(Photo courtesy Rugged Country Plants)

Eriogonum ovalifolium
var. *nivale*

Eriogonum ovalifolium (Oval-leaf Buckwheat): This is a widespread species with several unique and distinct varieties. All have evergreen, spoon-shaped, silver to silver-green leaves. All form tight foliar mats or mounds that are 3 to 5 inches tall and up to 12 inches wide. The attractive leaf mats have four-season beauty and are the hallmark of this species. All varieties produce pom-pom flowers with a single capitate head on each stalk. Bloom time is May into June.

Var. *nivale*: is found mainly in the Sierra Nevada Mountains of California and Nevada. The best forms produce white flowers that fade to soft pink as they age. The flower heads grow on short stalks and sit on top of or just above the foliage.

Var. ***purpureum*:** is widespread and can be found in all states west of the Great Plains except Washington. It produces flowers

Eriogonum ovalifolium
var. *purpureum*

heads on long (up to 10 inches), stiff, radiating stalks. The flowers come in various shades of white, pink, and red. The best forms have flowers that are pink to light red at anthesis then fade with age into intense shades of red or red-purple.

Eriogonum ovalifolium var. *depressum*

Var. *depressum*: is common in Idaho, Montana, and Wyoming. This is a very low growing form of the species. The flowers grow on very short stalks and may sit laxly on the foliage or at the other extreme be tucked deeply into the leaves. The best forms have large flower heads that sit on the foliage, are red at anthesis, and express a dark, intensely red color with age.

Eriogonum strictum var. ***proliferum*** (Strict Buckwheat): The white-flowered *proliferum* expression of this species is sometimes difficult to separate from *Eriogonum niveum*. However, these plants and their pink-flowered companions are the best forms of the species. The semi-deciduous, spoon-shaped leaves are silver to silver green in color. They form semi-spherical mounds up to 8 inches tall. Numerous 10 to 15" flower stalks radiate from the center of the plant. Bright white or soft pink flowers in small clusters cap heavily branched umbels. The bloom period is relatively late and very long, lasting from July into October.

Eriogonum strictum var. *proliferum*

Subgenus Oligogonum

Eriogonum arcuatum var. ***xanthum*** (Jame's Buckwheat): This species is closely related to *Eriogonum jamesii* var. *flavescens*. It is native to alpine and subalpine sites along the backbone of the Colorado Rockies. This attractive species has fuzzy gray-green leaves that form dense, evergreen mats. Older plants may be over two feet across but never more than about 6 inches tall. Hundreds of bright yellow flowers hover just above or are

Eriogonum arcuatum var. *xanthum*

slightly embedded into the foliage. The bloom period is from May into July. The interesting and attractive foliage means this plant is never out of season.

Eriogonum caespitosum

Eriogonum caespitosum (Mat Buckwheat): This unique species has an extensive ecological range and an array of forms that differ in color and size of leaves. It grows from Montana to Oregon and south to California and Arizona. A dense, creeping growth habit and silver-gray evergreen leaves make this a great rock garden plant. Leaf mats on mature plants are seldom more than three inches tall but may be two or more feet across. In expression of height, flowers vary from being embedded into the foliage to forming small dropping heads on six inch stalks. The species is dioecious and flower color differs by sex, with flowers on male plants usually yellow, while those on female plants vary from pinkish-yellow to dark red.

Eriogonum compositum (Arrowleaf Buckwheat): To a degree, this species has been exploited for garden production in Europe, but less so in the U.S. The native range includes western Idaho, eastern Oregon and Washington, and northern California. Arrowleaf buckwheat is among the most unusual of the *Eriogonum* species. It has very large, dark green leaves that are distinctly lance-shaped. The leaves are deciduous but during the summer form a loose, semi-spherical mound 8 to 10 inches tall. The leaves turn dark red in fall for some forms of the species. Huge umbels of dark yellow flowers rise 10 to 15 inches above the foliage and provide an incredible color display in June and July.

Eriogonum compositum

Eriogonum douglasii var. *douglasii*

Eriogonum douglasii var. ***douglasii*** (Douglas Wild Buckwheat): Limited distinction among botanical varieties of this species lead to the conclusion that all are worthy of cultivation. The var. *douglasii* is found mostly in the Blue Mountains of northeastern Oregon and southeastern Washington. The prominent feature of these plants is the strikingly silver color of the leaves. The foliage forms mats much wider (over 12 inches) than tall (up to 4 inches). The dark yellow pom-pom flowers appear in early spring, typically May into early June.

Eriogonum heracleoides (Wyeth's Buckwheat): This species can be found throughout the mountain west. Depending on provenance, variability in this species is tremendous and most of the accessions evaluated have been unremarkable. The best accession of this species identified to date was collected in the Mesa Falls area, in Fremont County, Idaho. It has relatively large, wide, olive colored leaves that form a mound up to a foot tall. The leaves can be evergreen under the protection of snow cover, but tend to be deciduous when unprotected. In May to July, numerous large umbels of creamy white flowers grow on 12 to 15 inch stalks.

Eriogonum heracleoides

Eriogonum jamesii (Jame's Buckwheat) has a number of distinct botanical varieties and a wide range of morphological expression. Common characteristics within the group include a dense, herbaceous basal leave mat, long spoon-shaped leaves the are often arranged vertically, dense pubescence on both leaf surfaces, large spherical flower heads, and flower heads arranged in complex, multi-layered umbels. All of the taxa in this species have horticultural potential. The two varieties evaluated at Aberdeen that have performed exceptionally well are var. *jamesii* and var. *flavescens*.

Eriogonum jamesii var. jamesii

Var. *jamesii*: is common in the southeastern Rocky Mountains and adjacent plains, specifically in Colorado, Texas, and Oklahoma. The deciduous leaves of this variety are long and tend to radiate from the center of the plant, resulting in a fairly symmetrical mound. The leaves are moderately hairy and in some expressions show marked reddish-purple highlights. The leaves turn pleasing tones of red and purple in fall. The prolific, small, cream colored flowers are clustered into numerous tight balls which are borne on compound umbels. The 12 inch flower stalks start out upright but often droop outward as the flowers become heavy. The extended bloom period lasts from June into September.

Var. *flavescens* (Jame's Buckwheat): This variety of the species is somewhat removed, both in native range and physical appearance, from the principal variety. It can be found in Wyoming, western Colorado, southeastern Utah, and northern Arizona and New Mexico. It has the same long, fuzzy leaves as the type variety, although it lacks the reddish overtones. The individual flower heads are dark yellow, less numerous, and significantly larger than those of its cream-colored counterpart. The inflorescences are compound and held above the foliage on 12 inch stalks. Bloom period is from June through August.

Eriogonum jamesii var. flavescens

Eriogonum umbellatum (Sulphurflower Buckwheat): The sulphurflower complex is the most variable among wild buckwheat species. It includes many landscape-worthy forms, with some being previously exploited on a commercial scale. Although there are exceptions to this general description, most plants within the *Eriogonum umbellatum* group have evergreen leaves that range in color from dark green to silver. Many forms exhibit beautiful fall leaf color in hues of red and purple. Flowers are typically yellow, although cream or white is more typical in some varieties. Bloom times vary widely, from early spring to early fall. Height of plants in bloom also varies widely, from a few inches to more than two feet.

Var. ***umbellatum*****:** is the type variety, the source of the common name, and is the stereotypically familiar form. The leaves are dark green and can form large mats up to a foot high and three feet wide. The flowers are dark yellow, arranged in simple umbels, and rise another 10 to 12 inches above the foliage. The bloom period is intermediate among varieties of the species, typically June into August.

Eriogonum umbellatum
var. *umbellatum*

Eriogonum umbellatum
var. *ellipticum*

Var. ***ellipticum*****:** is a tall, upright, late blooming form of the species. The leaves are relatively large, dark green, and form loosely arranged mats approximately 8 inches tall and a foot wide. The flowers open dark yellow age into remarkable tones of red and orange. They are arranged in large, compound umbels, and are held 15 to 18 inches above the foliage. The bloom period is late, usually July to September.

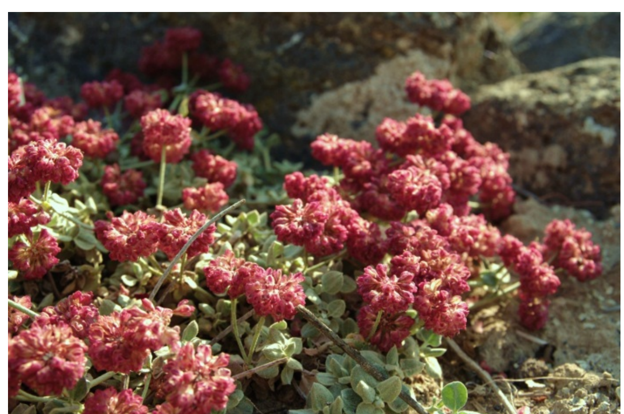
Var. ***dichrocephalum*:** is unlike most of the other varieties in the genus. The leaves are similar to many of the other forms, being dark green, and forming mats up to six inches high and 18 inches wide. However, the flowers are cream-colored or sometimes very light yellow. With most forms of this variety, the flowers age to pink or red, and many hold a dark red color for many weeks. The flowers grow on short stems, six to eight inches long. The umbels are simple. The bloom period is early, typically June and July.

Eriogonum umbellatum
var. *dichrocephalum*

Eriogonum umbellatum
var. *porteri*

Var. ***porteri*:** looks like a dwarf form of var. *dichrocephalum*. Both have simple flower umbels. The leaves are dark green but the mats are tight and seldom more than 3 inches tall (up to 12 inches across). The flowers are light to medium yellow, aging red, and sit at the top of the foliage. In bloom, the entire plant is seldom more than 5 inches tall. The bloom period is early, June to July.

Var. ***minus*:** is a very distinct expression of the species, differing in morphology from the type variety in many ways. The leaves are very light silvery green. The foliage mats are very flat, often less than an inch tall, and only about 8 inches across for mature plants. The flower buds are a deep wine red color. From the time they first open, the flowers are dark maroon. The simple umbellate flower heads grow on five to six inch decumbent stems causing the flowers to lie flat on the foliage or the ground around the plants.



Eriogonum umbellatum
var. *minus*

Conclusion:
Expressions among the genus *Eriogonum* include many exploitable garden-worthy species. These plants have high potential to become valuable additions to water-conserving plant palettes for use by landscape designers in the Intermountain West. Plant domestication research involving this group of plants will continue and possibly expand to include additional species and accessions.

References:

Reveal, J.L. 2003. *Eriogonum* as a rock garden plant. University of Maryland Dept. of Plant Biology. www.plantsystematics.org/reveal/pbio/eriog/eriogarden.html.

Vegetative propagation of native plants for landscape use

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Abstract

Utah State University and the USU Botanical Center are committed to the goal of maintaining the quality of life enjoyed through landscaping while conserving water in those landscapes. One of the primary means of achieving that goal is through the use of water-conserving plants. Bigtooth maple (*Acer grandidentatum*) has been identified as a native Utah tree with potential for use in water-conserving landscapes. In 2012 we continued research on mound layering of native plants and cutting propagation of Utah juniper. Mound layering has been successful with bigtooth maple, chokecherry, curl-leaf mountain mahogany, littleleaf mountain mahogany, and Gambel oak. Cutting propagation of Utah juniper can be successful given adequate time (16 weeks) and appropriate hormone treatments.

Introduction

Past research at Utah State University has focused on the identification of native plant accessions with potential for use in water conserving landscapes. A key part of this project is the development of propagation protocols for selected accessions. In some cases, such as bigtooth maple, we have been successful in developing methods of cutting propagation. As a result, we have now turned our efforts to the development of mound layering as a sustainable method of propagating mature accessions. In other cases, such as Utah juniper, simple vegetative propagation remains elusive and we are continuing to work toward the development of protocols that will permit effective rooting of cuttings.

Mound Layering of Bigtooth Maple - 2011

Bigtooth, or canyon, maple (*Acer grandidentatum*) is of interest due to its potential use in low-water landscaping. It is a difficult plant to propagate vegetatively and more efficient propagation may facilitate both the introduction and commercial production of new selections from the wild. Bigtooth maple is known to propagate itself naturally by layering. The objective of this study was to evaluate mound layering as a means of vegetatively propagating selected accessions of mature bigtooth maple trees.

Materials and Methods

Rooted cuttings of five accessions of mature wild bigtooth maple (USU-ACGR-1001, 1002, 1003, 1004, 1005) were established in a mound layer bed at the Utah State University Botanical Center in Kaysville, Utah from 2008 to 2010 (Fig. 1). Stock plants were placed in rows by variety with spacing of 6 foot (between rows) by 3 foot (in row). Alleys were covered with weed barrier; with conifer shavings used as a mulch and mounding material. Stock plants were partially mounded in early summer of 2011 and on 11 July plants with at least 4 shoots were selected for layering. Mounding material was removed and each of 4 shoots per plant were randomly assigned a treatment of either a girdle, rooting hormone, or both girdle and rooting hormone applied to the stem base, or an untreated control. Girdling was done by tightly applying a 4 x 0.10-inch cable tie as low as possible on the stem. The hormone treatment consisted of 4000 ppm IBA and 2000 ppm NAA as Dip'N Grow® in 25% ethanol applied with a cotton swab to the basal one-inch of the shoot. Shoots were then mounded with conifer shavings. Stock plants were sprinkler irrigated for 5 minutes twice daily. Rooted layers were harvested on 28 October 2011 by cutting the stem at the base (Fig. 2). Roots per shoot and percent rooting was determined and data analyzed using a generalized linear mixed model using SAS PROC GLIMMIX. Roots per shoot were analyzed using a square-root transformation. Percent rooting was determined by counting each shoot as a binary response and modeling based on probability of rooting.

Fig. 1. Bigtooth maple mound layer bed with conifer shaving rooting substrate.

Fig. 2. Roots on layered shoots of bigtooth maple at harvest (28 October 2011)

Results and Discussion

These results indicate that both girdling and auxin application can increase the percentage of rooted layers with bigtooth maple, and that combining the two treatments together results in a significant increase in percent rooting and roots per layer (Figs. 3 and 4). We conclude that mound layering, in combination with a rooting hormone and stem girdling can be an effective means of propagating mature bigtooth maple.

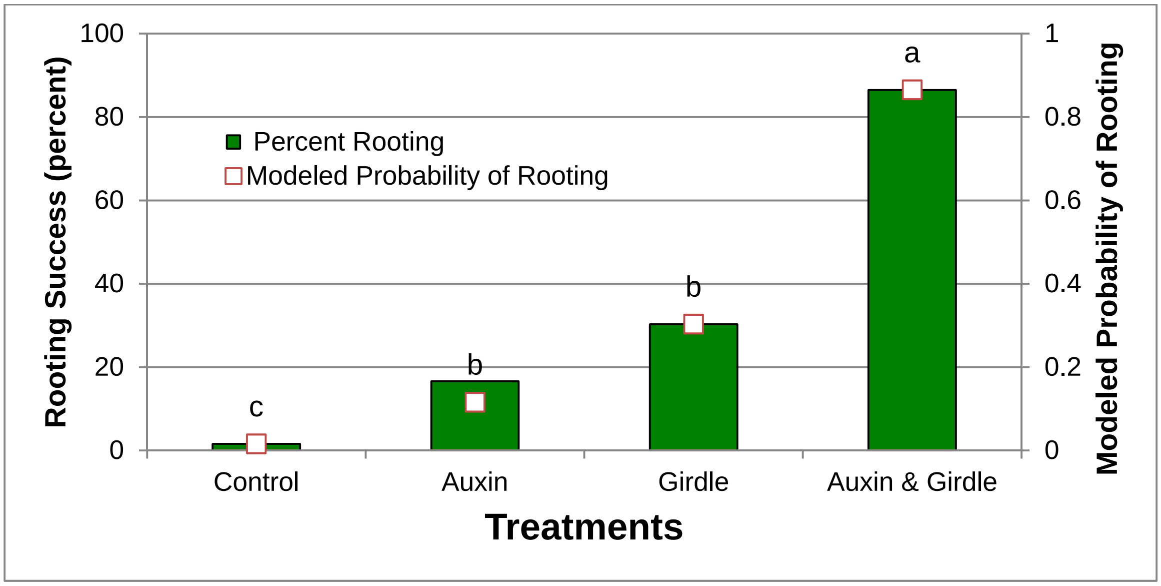

Fig. 3. The effect of auxin (4000 ppm IBA and 2000 ppm NAA as Dip'N Grow® in 25% ethanol) and girdling; either singly or combined on the percentage of rooted shoots when layering bigtooth maple. Means of modeled data with a different letter are statistically different as based on analysis using PROC GLIMMIX with each shoot being a binary response and modeled as probability to form roots.

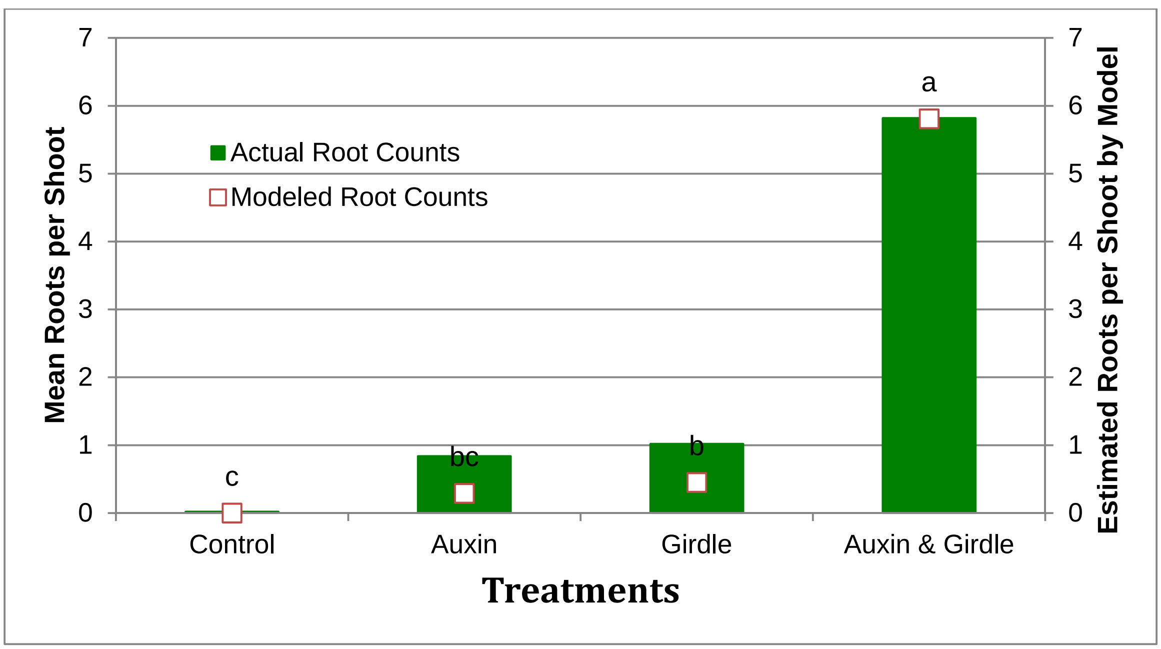

Fig. 4. The effect of auxin (4000 ppm IBA and 2000 ppm NAA as Dip'N Grow® in 25% ethanol) and girdling; either singly or combined on the average number of roots per shoot developed when layering bigtooth maple. Means from modeled data with a different letter are statistically different as based on square-root transformed data analyzed with GLIMMIX.

Mound Layering of Bigtooth Maple – 2012

In 2012 we endeavored to repeat the mound layering experiment of 2011. The treatments were basically the same, with the following differences. The spring and summer of 2012 was warmer and drier than the spring and summer of 2011. Comparing the period of April 1 to August 31 in both years, the year 2011 had 12.9 cm more rain, was 3.3°C cooler, and had 0.72 mm/day less reference evapotranspiration. In addition, treatments were applied 13 days earlier in 2012, and no mounding was done prior to application of the treatments. Preliminary results of this experiment indicate a very similar pattern to 2011, but at much lower levels of rooting. The control treatment produced 1% rooting, auxin 3%, girdling 13%, and the combined treatment produced 35% rooting (Table 1). While warmer, drier conditions can impact plant growth and development, under irrigated conditions it is doubtful that the climatic conditions reduced rooting. We surmise that it was the lack of early mounding and subsequent blanching of shoots that reduced rooting.

In 2012 we also conducted preliminary experiments with mound layering of seedling-grown Gambel oak (*Quercus gambelii*) and curl-leaf mountain mahogany (*Cercocarpus ledifolius*) as well as clonal selections of littleleaf mountain mahogany (*Cercocarpus ledifolius* var. *intricatus*) and chokecherry (*Prunus virginiana*). Treatments were similar to those used with bigtooth maple, with the following variations. Layering of littleleaf mountain mahogany was done on July 11, 2012. Layering of curl-leaf mountain mahogany was done on June 29, 2012 and used a microspray irrigation system. Lastly, the only treatment applied to chokecherry was girdling.

While all 2012 results are preliminary and have not been test for statistical significance, it is apparent that layering can be used to propagate both Gambel oak and the two mountain mahogany species tested, and that girdling and/or auxin treatments generally enhance rooting. There is also an indication that careful etiolation during shoot development of maple, and possibly the other plants as well, is critical to effective rooting.

Table 1. Preliminary data on the effect of girdling and auxin treatments (separate and combined) on the rooting of three native woody plants.

Treatment	**Percent Rooting**			
	Quercus gambelii	***Cercocarpus ledifolius***	***C. ledifolius* var. *intricatus***	***Prunus virginiana***
Control	3	52	0	54
Girdle	18	76	0	50
Auxin	6	73	0	-
Girdle and Auxin	15	88	44	-

Cutting Propagation of *Juniperus osteosperma* (Utah juniper)

As a drought tolerant plant, Utah juniper has potential for use in water-conserving landscapes. Certain specimens of Utah junipers found in the wild have unique phenotypes that make them attractive options for landscape design. Such phenotypic characteristics can only be perpetuated through asexual propagation techniques, such as cutting propagation. Unfortunately, Utah juniper, like other upright juniper species, is not easily propagated vegetatively. To our knowledge Reinsvold (1986) is the only published record of Utah juniper being propagated by cuttings; unfortunately, the focus of the study was not cutting propagation of Utah juniper and so insufficient data were included for replicating the study. The purpose of this research was to develop a propagation protocol for Utah juniper.

Materials and Methods

Terminal cuttings were collected from 15 wild Utah junipers in Park Valley, UT on 16 Nov 2010 and 19 Nov 2011. The cuttings were taken only from apparently juvenile plants which were characterized as possessing no strobili (cones) and having predominately awn-like leaves. Both years, the same GPS-marked trees were used as stock plants in order to maintain uniformity in plant material across years. After harvesting, the cuttings were placed in moist plastic bags and stored in a cooler with ice for transporting back to the greenhouse in Logan, UT. They were then stored overnight at 4°C and processed the following day. Cuttings from all stock plants were pooled, cleaned, and 288 of the most uniform cuttings were cut to size (15 cm) and randomly assigned to one of 16 different treatments with 18 cuttings per treatment.

The experiment was a factorial design with four IBA concentrations (0, 1000, 3000, or 8000 ppm IBA as either no treatment or Hormodin® 1, 2, or 3, respectively); two rooting substrate types (2:1 or 4:1 perlite:peat by volume); and two different rooting environments (an open mist bench or a mist bench enclosed by a white polyethylene tent; Fig. 5). Cuttings were stripped of foliage from the bottom 4 cm and wounded by cutting down to the secondary xylem at 15 mm on one side of the cutting and scraping off the bark from that point down to the bottom end. The wounded region was then moistened and dipped in the appropriate hormone to a depth of 15 mm. Immediately afterwards, each cutting was stuck in its respective, pre-moistened media type in 606 flats (63.5 x 63.5 x 76.2 mm cells) and placed on the bench within its respective rooting environment (Fig. 5). All cuttings were in the same greenhouse with 18/15.5 °C day/night temperature set points, 16 hour days, and bottom heat at 21 °C. The cuttings were intermittently misted on the open mist bench for 7 sec every 30 min and in the polyethylene tent for 30 sec at 9:00AM, 1:00PM, and 5:00PM. Misting was with de-ionized water and cuttings were irrigated as needed with culinary water. There were 3 replications per treatment, with each consisting of six cuttings in individual cells in the six-packs.

Both years, at 8 weeks post-sticking, all cuttings were removed from the media and analyzed. Both rooted and un-rooted cuttings were re-stuck in their respective cell and returned to their previous conditions. In 2010, rooting data from cuttings rooted at 8 weeks was combined with that of newly rooted cuttings at 16 weeks for the final analysis. In 2011, all cuttings were re-analyzed at 16 weeks for the final analysis. Presence of roots, number of roots per cutting, length of longest root, presence of callus, and foliar status were noted.

A generalized linear mixed model was used to analyze the data collected for both years at 16 weeks. The model was developed to predict the effect of each experimental variable on rooting and the number of roots. Since rooting for each cutting was a binary response (rooted or non-rooted), root development was modeled as the probability of rooting. For the number of roots, only rooted cuttings were analyzed. The original number of roots were square-root transformed and then analyzed using the mixed model. All analyses were performed using the PROC GLIMMIX package in SAS 9.3.

Results and Discussion

In 2011 and 2012, at 8 weeks post-sticking, 6% and 4% of the cuttings rooted, respectively; however, at 16 weeks, the total fraction of rooted cuttings was greater: 24% and 26%, respectively (Fig. 6). As IBA concentrations increased, both frequency of rooting and number of roots increased (both p-value < 0.0001). Rooting was also more frequent in the 2:1 media compared to the 4:1 (p-value = 0.0072). In the white polyethylene tent, rooting was more frequent compared to the mist bench (p-value = 0.0409) and the foliage appeared healthier (data not quantified). Neither media nor environment had an effect on number of roots.

Conclusion

In both 2011 and 2012, the highest rooting percentages (66% and 72%, respectively) were found in the 8000 ppm IBA, 2:1 perlite:peat treatment in the polyethylene tent. We recommend using these variables for successfully propagating Utah juniper.

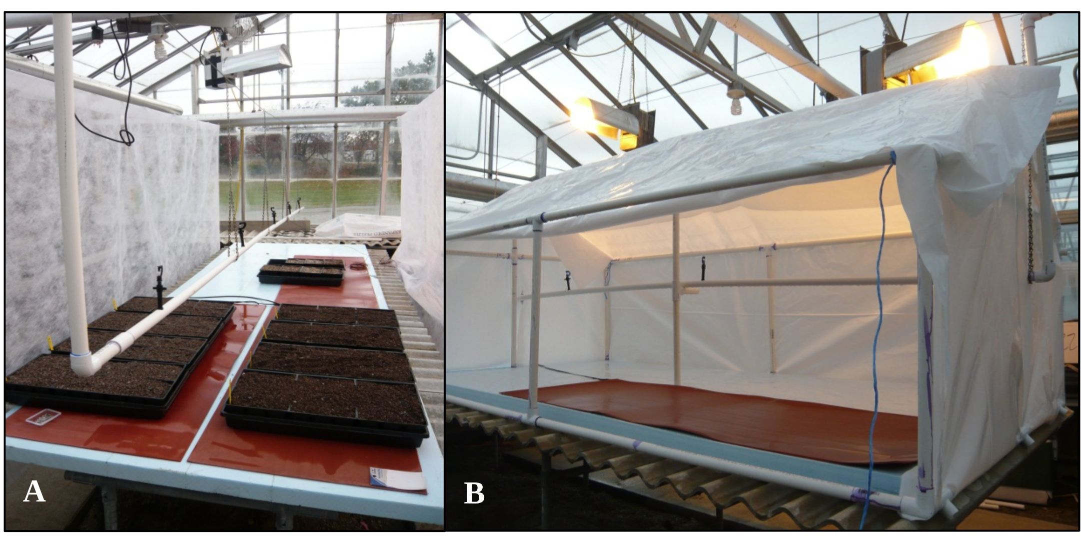

Fig. 5. *(A) Mist bench and (B) Polyethylene tent environments used for propagating the Utah juniper cuttings both years.*

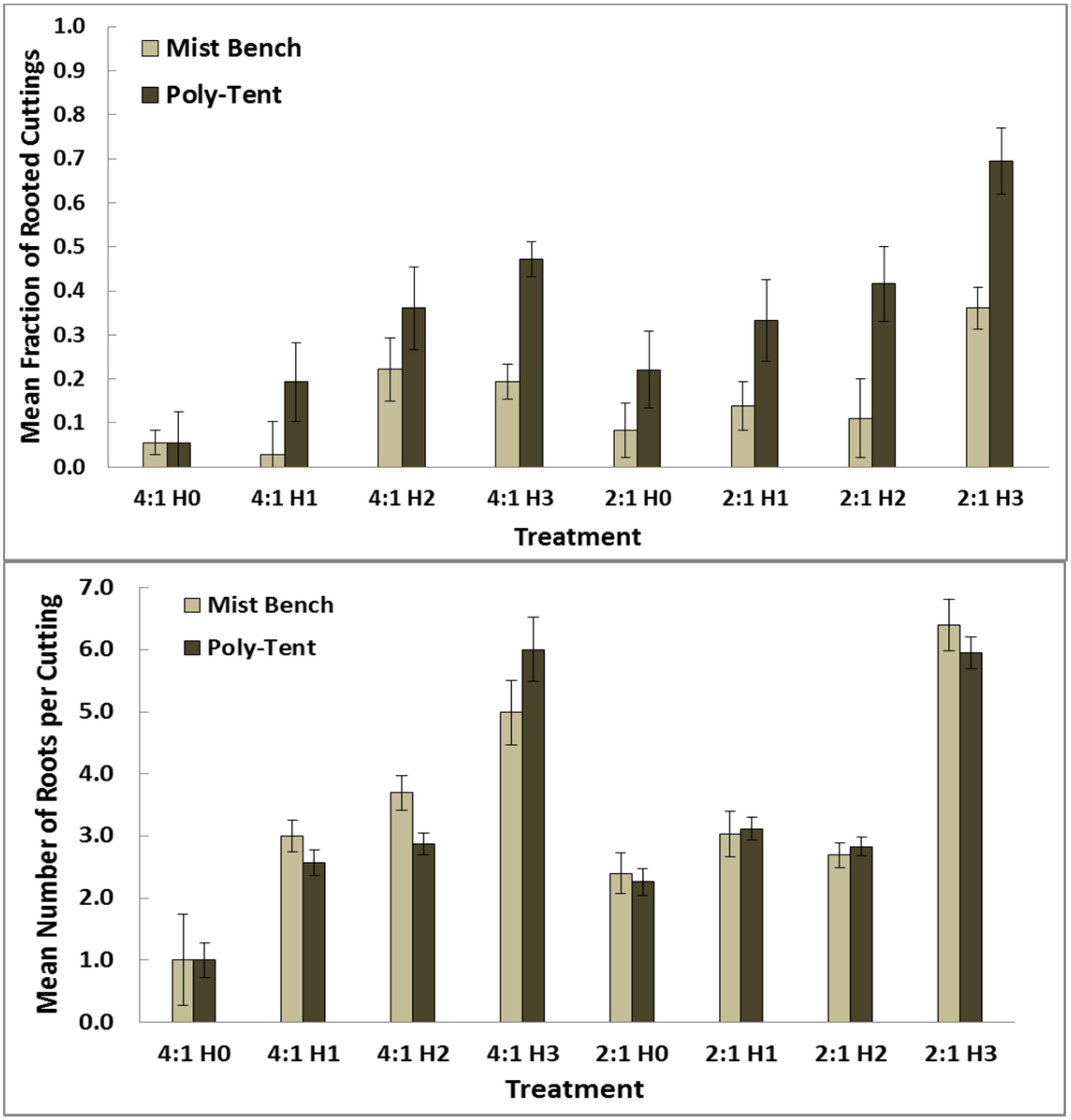

Fig. 6. Effect of rooting hormone, rooting substrate, and bench environment on the mean fraction of rooted cuttings (top) and the number of roots per rooted cutting (bottom). Treatments and abbreviations are: 4:1 and 2:1 perlite:peat (4:1 or 2:1); 0, 1000, 3000, and 8000 ppm IBA as Hormodin 1, 2, or 3 (H0, H1, H2, and H3). Data is combined over 2011 and 2012 with the standard error of the mean determined (error bars).

Using SNP markers to understand phylogenetic relationships of 82 *Penstemon* taxa

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There are more than 270 *Penstemon* species identified with centers of origin in, or near, the Great Basin/Colorado Plateau (Straw, 1966; Wolfe et al., 2002; Wolfe et al., 2006). We have identified 69 *Penstemon* species (93 taxa) native to Utah, more than any other state. Of these 69 species, 21 are endemic to the state with another 24 found in Utah and one adjacent state. By way of comparison there are a total of 80 species reported in Washington, Oregon, Idaho, and Montana (Strickler, 1997), while there are 63, 61, 54, 51, and 45 species in Colorado, California, Nevada, New Mexico and Wyoming respectively (Database, 2012; Heflin, 1997).

Penstemon of the Intermountain West are morphologically and cytogenetically diverse and adapted to a wide range of environments, although, the majority thrive in rocky, xeric conditions (Broderick et al., 2011; Holmgren, 1984; Lindgren and Wilde, 2003; Nold, 1999; Welsh et al., 2008; Wolfe et al., 2006). A number of these species have superior ornamental potential due to their conspicuous flowers, attractive foliage, and drought tolerance (Broderick et al., 2011; Dockter et al., 2012; Lindgren and Wilde, 2003; Lindgren, 2000; Nold, 1999; Way and James, 1998).

In Europe, *Penstemon* breeding has taken place for over a century but little has been done with xeric species (Way and James, 1998). In part, this is due to hybridization barriers frequently encountered between many drought tolerant species (Uhlinger and Viehmeyer, 1971). Few modern plant breeding tools and methodologies have been applied to overcome these barriers (Lindgren, 2000; Lindgren and Schaaf, 2007). However, declining cost of molecular tools could aid in the interspecific breeding within this genus (Cronn et al., 2012; Dockter, 2011; Maughan et al., 2011; Maughan et al., 2009).

In our lab we identified 431 homologous contigs with potential interspecific single nucleotide polymorphisms (SNPs) in comparisons between *P. davidsonii* × *P. cyananthus* and *P. davidsonii* × *P. dissectus* (Dockter, 2011). Of those contigs, we selected 192 for SNP marker development with 75 (39%) of these producing reliable results across 86 samples (85 unique taxa [Table 1]). Of those 75, seven were found to be polymorphic between *P. davidsonii* and all other inclusive species; eight were identified between *P. dissectus* and all other inclusive species; whereas, there were no SNPs found unique to *P. cyananthus* (Fig. 1). However, this lack of distinctive markers for *P. cyananthus* is associated with the tightly related clade of 34 species (43 taxa) in which it is a member and where five SNPs differentiate among them. Closely related genera *Keckiella lemmonii*, *Nothochelone nemorosa*, and *Chelone obliqua* were utilized as outgoups in this study. Of the 83 *Penstemon* used in this study, 82 were unique *Penstemon* taxa; 70 were independent species representing five (*Dasanthera*, *Dissecti*, *Habroanthus*, *Penstemon*, and *Saccanthera*) of the six subgenera of the genus (Table 1; Fig. 1). As in previous studies, we found that taxa tested from the subgenera *Dissecti*, *Habroanthus*, *Penstemon*, and *Saccanthera* are polyphyletic with the *Dasanthera* species being the only ones to separate distinctly from the other species. Even though these subgenera do appear to be polyphyletic, many species of the presently classified sections and subsections had a proclivity to group into clades. However, unique to previous reports (Straw, 1966; Wolfe et al., 2006), our data suggest that *N. nemorosa* and *K. lemmonii* may be better classified as subgenera of *Penstemon*.

We have demonstrated that random *Penstemon* interspecific SNP markers can be relatively easily identified and utilized inexpensively. These SNPs have at least two potential uses in *Penstemon* breeding beyond their use in phylogenetics. First, they can be genetically mapped in carefully designed interspecific crosses. Second, they can be used in the monitoring of the introgression of chromosomal segments during interspecific hybridization. These and additional interspecific SNPs will be invaluable tools in *Penstemon* phylogenetics and breeding programs.

Table 1. Collection sites and sources of *Penstemon* and related taxa used in this study. These species were selected because they are mostly native to the Intermountain West of the United States (with a few exceptions). *Penstemon* subgenera are colored coded to match the color designations in the Fig. 1 phylogenetic tree.

Taxa	I.D. #[1]	Collection site/Source[2]
Genus *Chelone*		
C. obliqua L.		A1
Genus *Keckiella*		
K. lemmonii		A2
Genus *Nothochelone*		
N. nemorosa (Douglas ex Lindl.) Straw		A3
Genus *Penstemon*		
Subgenus *Dasanthera*		
P. davidsonii Greene		B
P. montanus var. *montanus* Greene	#081	Utah Co., UT
Subgenus *Dissecti*		
P. dissectus Elliott		C
Subgenus *Habroanthus*		
Section *Elmigera*		
P. barbatus var. *trichander* A. Gray	#165	San Juan Co., UT
P. eatonii var. *eatonii* A. Gray	#082	Utah Co., UT
Section *Habroanthus*		
P. ammophilus N. Holmgren & Shultz	#015	Kane Co., UT
P. comarrhenus A. Gray	#075	Garfield Co., UT
P. compactus (Keck) Crosswhite	#188	Cache Co., UT
P. cyananthus var. *cyananthus* Hooker	#051	Utah Co., UT
P. cyananthus var. *subglaber* (A. Gray) N. Holmgren	#159	Box Elder Co., UT
P. cyanocaulis Payson	#104	Emery Co., UT
P. fremontii Torrey & Gray	#037	Duchesne Co., UT
P. gibbensii Dorn	#016	Daggett Co., UT
P. idahoensis Atwood & Welsh	#050	Box Elder Co., UT
P. laevis Pennell	#118	Kane Co., UT
P. leiophyllus var. *leiophyllus* Pennell	#068	Iron Co., UT
P. longiflorus (Pennell) S. Clark	#066	Beaver Co., UT
P. navajoa N. Holmgren	#178	San Juan Co., UT
P. parvus Pennell	#076	Garfield Co., UT
P. pseudoputus (Crosswhite) N. Holmgren	#073	Garfield Co., UT
P. scariosus var. *albifluvis* (England) N. Holmgren	#141	Uintah Co., UT
P. scariosus var. *cyanomontanus* E. Neese	#142	Uintah Co., UT
P. scariosus var. *garrettii* (Pennell) N. Holmgren	#034	Duchesne Co., UT
P. scariosus var. *scariosus* Pennell	#140	Sevier Co., UT
P. speciosus Douglas ex Lindley	#155	Box Elder Co., UT
P. strictiformis Rydberg	#077	San Juan Co., UT
P. strictus Bentham	#176	Wasatch Co., UT
P. subglaber Rydberg	#046	Sevier Co., UT
P. tidestromii Pennell	#128	Juab Co., UT
P. uintahensis Pennell	#182	Uintah Co., UT
P. wardii A. Gray	#042	Sevier Co., UT
Subgenus *Penstemon*		

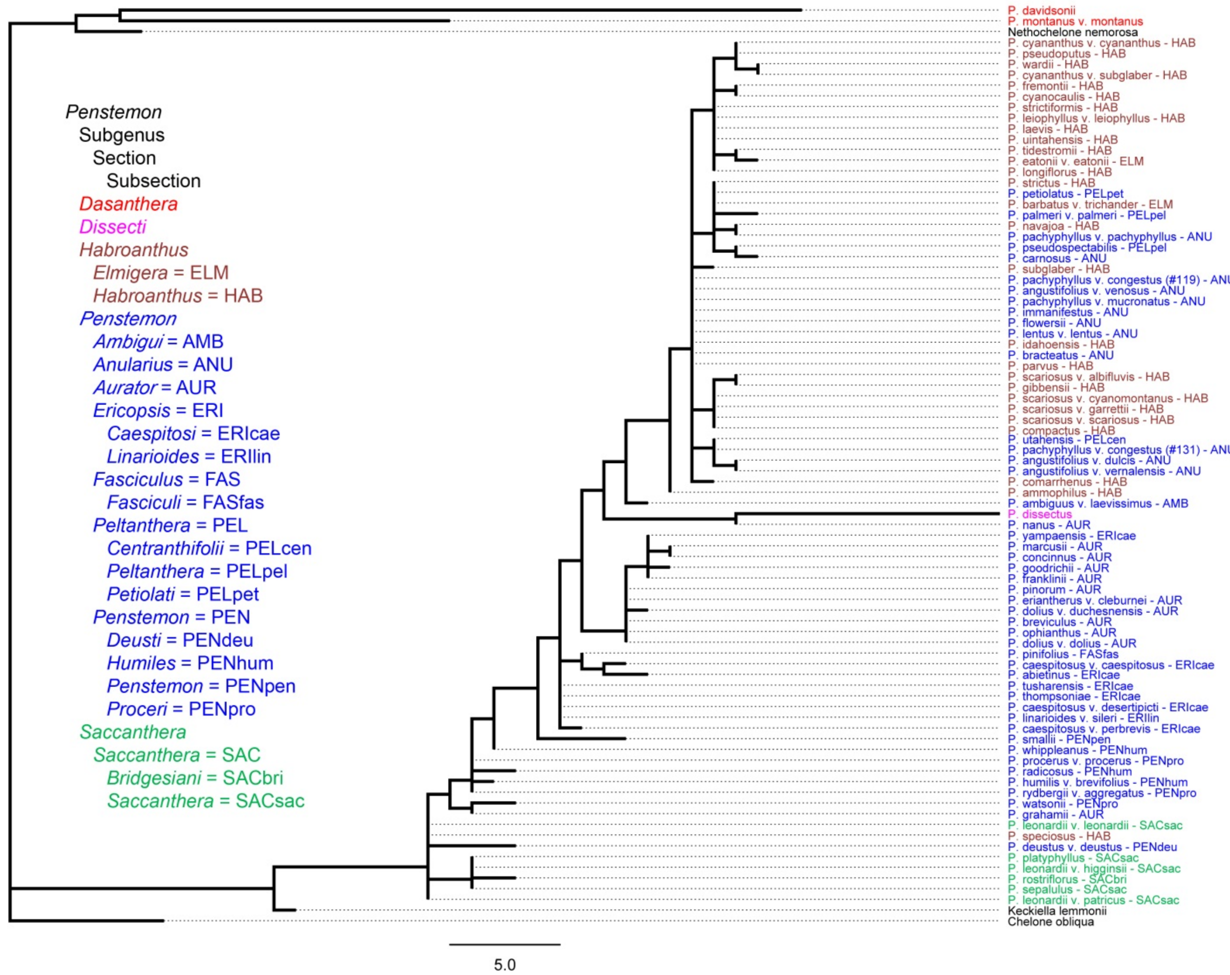
Taxa	I.D. #[1]	Collection site/Source[2]
Section *Ambigui*		
P. ambiguus var. *laevissimus* (D.D. Keck) N.H. Holmgren	#115	Washington Co., UT
Section *Anularius*		
P. angustifolius var. *dulcis* E. Neese	#110	Millard Co., UT
P. angustifolius var. *venosus* (Keck) N. Holmgren	#095	San Juan Co., UT
P. angustifolius var. *vernalensis* N. Holmgren	#017	Uintah Co., UT
P. bracteatus Keck	#174	Garfield Co., UT
P. carnosus Pennell	#096	Emery Co., UT
P. flowersii Neese & Welsh	#039	Uintah Co., UT
P. immanifestus N. Holmgren	#113	Millard Co., UT
P. lentus var. *lentus* Pennell	#002	San Juan Co., UT
P. pachyphyllus var. *congestus* (M.E. Jones) N. Holmgren	#119	Kane Co., UT
P. pachyphyllus var. *congestus* (M.E. Jones) N. Holmgren	#131	Beaver Co., UT
P. pachyphyllus var. *mucronatus* (N. Holmgren) Neese	#029	Daggett Co., UT
P. pachyphyllus var. *pachyphyllus* A. Gray ex Rydberg	#035	Duchesne Co., UT
Section *Aurator*		
P. breviculus (Keck) Nisbet & R. Jackson	#094	Garfield Co., UT
P. concinnus Keck	#130	Beaver Co., UT
P. dolius var. *dolius* M.E. Jones ex Pennell	#112	Millard Co., UT
P. dolius var. *duchesnensis* N. Holmgren	#100	Duchesne Co., UT
P. eriantherus var. *cleburnei* Pursh	#030	Daggett Co., UT
P. franklinii S.L. Welsh	#006	Iron Co., UT
P. goodrichii N. Holmgren	#125	Uintah Co., UT
P. grahamii Keck	#124	Uintah Co., UT
P. marcusii (Keck) N. Holmgren	#098	Emery Co., UT
P. nanus Keck	#114	Millard Co., UT
P. ophianthus Pennell	#136	Garfield Co., UT
P. pinorum L. & J. Schultz	#008	Washington Co., UT
Section *Ericopsis*		
Subsection *Caespitosi*		
P. abietinus Pennell	#045	Sevier Co., UT
P. caespitosus var. *caespitosus* Nutt. Ex A. Gray	#144	Daggett Co., UT
P. caespitosus var. *desertipicti* (A. Nels.) N. Holmgren	#009	Washington Co., UT
P. caespitosus var. *perbrevis* (Pennell) N. Holmgren	#055	Wasatch Co., UT
P. thompsoniae (A. Gray) Rydberg	#093	Kane Co., UT
P. tusharensis N. Holmgren	#064	Beaver Co., UT
P. yampaënsis Pennell	#027	Daggett Co., UT
Subsection *Linarioides*		
P. linarioides var. *sileri* A. Gray	#085	Washington Co., UT
Section *Fasciculus*		
Subsection *Fasciculi*		
P. pinifolius Greene		D
Section *Peltanthera*		
Subsection *Centranthifolii*		
P. utahensis Eastwood	#092	San Juan Co., UT

Taxa	I.D. #[1]	Collection site/Source[2]
Subsection *Peltanthera*		
P. palmeri A. Gray	#011	Washington Co., UT
P. pseudospectabilis M.E. Jones		D
Subsection *Petiolati*		
P. petiolatus Brandegee	#010	Washington Co., UT
Section *Penstemon*		
Subsection *Deusti*		
P. deustus var. *deustus* Douglas ex Lindley	#192	Teton Co., WY
Subsection *Humiles*		
P. humilis var. *brevifolius* A. Gray	#061	Wasatch Co., UT
P. radicosus A. Nelson	#157	Box Elder Co., UT
P. whippleanus A. Gray	#181	Wasatch Co., UT
Subsection *Penstemon*		
P. smallii 'Violet Dusk' Heller		E
Subsection *Proceri*		
P. procerus var. *procerus* Douglas ex Graham	#184	Duchesne Co., UT
P. rydbergii var. *aggregatus* (Pennell) N. Holmgren	#158	Box Elder Co., UT
P. watsonii A. Gray	#145	Sevier Co., UT
Subgenus *Saccanthera*		
Section *Saccanthera*		
Subsection *Bridgesiani*		
P. rostriflorus Kellogg	#071	Washington Co., UT
Subsection *Saccanthera*		
P. leonardii var. *higginsii* Neese	#072	Washington Co., UT
P. leonardii var. *leonardii* Rydberg	#052	Utah Co., UT
P. leonardii var. *patricus* (N. Holmgren) Neese	#175	Tooele Co., UT
P. platyphyllus Rydberg	#154	Salt Lake, Co., UT
P. sepalulus A. Nelson	#153	Utah Co., UT

[1]I.D. #: The field notebook number connected with the herbarium samples curated at the S.L. Welsh Herbarium collection of the Monte L. Bean Life Science Museum, Brigham Young University, Provo, Utah.

[2]Collection site/Source: The county and state in which the sample was collected or the alternative source from where the sample was obtained. A, American Penstemon Society Officer Ginny Maffitt provided samples which she obtained from the following locations/sources (A1, Sherwood, OR; A2, Berry Botanic Garden, Portland, OR; A3, Milestone Nursery, Lyle, WA); B, seed purchased from www.alplains.com; C, plants purchased from www.woodlanders.net; D, seed purchased from www.westernnativeseed.com; E, plants purchased from www.lindennursery.com.

Fig. 1 Phylogenic Analysis Using Parsimony (PAUP) to create a neighbor joining tree. *Keckiella lemmonii*, *Nothochelone nemorosa*, and *Chelone obliqua* were used as out-groups. Color and three letter codes were used to quickly identify the present outline of the phylogenetic relationships of the *Penstemon* used in this study (Wolfe et al., 2006).



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