Report of the Intermountain Native Plants Cooperative

Volume 7 *December 2015*

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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Volume 7 – December 2015

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 aggressiveness of native plants in the urban landscapes and many other native plant related studies.

Cover: The photo on the cover was taken by Stephen Love and is of "Sandloving Penstemon" (*Penstemon ammophilus*), in blow sand derived from Navajo Sandstone Formations in the southern regions (Johnson Canyon) of Grand Staircase Escalante National Monument of southern Utah.

Announcements

2016 American Penstemon Society Annual Meeting will meet at the Fairmont, Montana, June 24-27, 2016. There will be tours in the region to see *Penstemon* and other native plants. For more details visit http://apsdev.org/aps/meetings.html

2016 The Eriogonum Society Annual Meeting will be out of Desert Studies Center (Baker), California, September 16 - 19. For details visit http://www.eriogonum.org/

2016 WERA Meeting will be hosted by Bill Graves in Ames, Iowa, October 7-8, 2016.

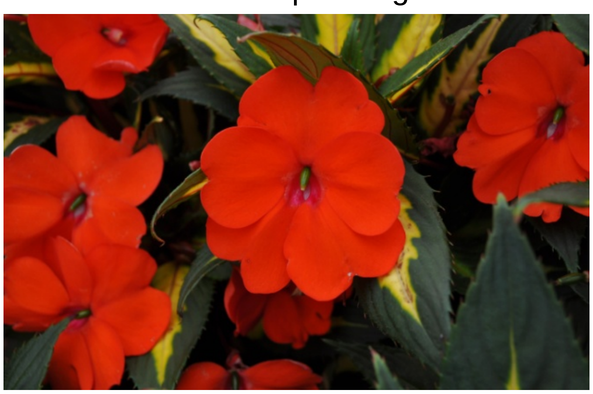
Colorado State University Ornamental Trials and Plant Select Program

James E Klett
Department of Horticulture and Landscape Architecture, Fort Collins, CO

1. Annual and Perennial Flower Evaluation Research

In 2015 approximately 800 different varieties of annuals, representing about 73 different genera, were grown and displayed in our research/display garden. The 2015 growing season started off rainy and cooler in May and June. In July relatively normal temperatures returned and August and September were very dry and quite warm. We had a very long fall with first freeze not coming until the end of October.

On August 3, 2015 approximately 100 industry personnel and advanced Master Gardeners judged the annuals in different taxa categories to determine “Best Of” awards in different categories. Sun New Guinea Impatiens ‘Sunpatiens® Spreading Tropical Orange’ from Sakata took “Best of Show 2015”. The electric orange flowers were vivid and had great contrast against the beautiful foliage. Our best new variety award was given to Lobularia ‘Raspberry Stream™’ from Danziger. The extreme flower power was combined with an intense raspberry color for an impressive display. Our ‘Best Novelty” award was given to Celosia ‘Dragon's Breath’ from Sakata. Flowers formed later in the season but had a two toned combination of burgundy and hints of florescent purple that seemed to glow. Twenty-four other varieties were chosen “Best Of” in each of the separate genera.



‘Sunpatiens Spreading Tropical

‘Dragon’s Breath’ celosia

‘Raspberry Stream’ Lobularia

Over one hundred new perennial taxa were planted in 2015 into our two-winter, three growing-season perennial trial. In November 2015, the committee chose nine 'Top Performers' from our 2013 planting and two "Too Good to Wait" from our 2014 trials.

Our 2015 perennial "Top Performers" included:

'Electric Avenue' coreopsis

'Electric Avenue' coreopsis from Creek Hill/Eason (*Coreopsis verticillata* 'Electric'); bright yellow flowers covered this plant over a long bloom period. 'Beyond Blue' fescue (*Festuca glauca* 'Casca11' PP #23307 from Skagit Gardens; this fescue had a true 'blue' color and did not open in the middle (Photo). Three Gold Collection® *Helleborus* from Skagit Gardens including 'Maestro' hellebore, 'Merlin' hellebore and 'Snow Fever'; all three survived two winters and had great foliage color. 'Little Lace'™ Russian sage (*Perovskia* 'Novaperlac') from Star Roses and Plants/The Conard-Pyle CO; the purple flowers were long lasting on a shorter plant with great uniformity. 'Sunrosa'™ red rose (*Rosa* X hybrid Sunrosa™ Red) from Suntory Flowers; the contrast, red flowers and impressive growth habit made this plant attractive all season. Two of Moody Blue™ series of veronicas from Star Roses and Plants/ The Conard-Pyle CO were also voted "Top Performers", 'Dark Blue Moody Blues'™ had abundant spikes of dark blue flowers and 'Pink Moody Blues'™ veronica had light pink flowers and a little taller growth habit.

Plant Select®

In 2015, six plants were either introduced through Plant Select® or recommended to the industry and gardening public. Also three additional plants were added to Plant Select® Petite Program.

'Beyond Blue' fescue

The three new Plant Select® introductions included: *Penstemon* x 'Coral Baby' (Coral Baby penstemon) which sports bouquets of coral pink flowers from May to July. *Salvia darcyi* x *Salvia microphylla* (Windwalker® royal red salvia), a robust grower with graceful stems crowned with blood-red flowers. The third introduction, *Andropogon gerardii* 'PWIN01S' ('Windwalker'® big bluestem) is a regal upright ornamental grass selected for its powdery blue foliage that turns plum-purple in September.

The three new recommended plants include; Engelmann's daisy (*Engelmannia peristenia*); 'Woodward' columnar juniper (*Juniperus scopulorum* 'Woodward' and desert beardtongue (*Penstemon pseudospectabilis*). The three Plant Select® petites for 2015 include: *Androsace sarmentosa* 'Chumbyi' (Silky rock jasmine), *Arenaria* 'Wallowa Mountain' (Desert Moss) and *Heterotheca jonesii* x *villosa* 'Goldhill' (Goldhill golden-aster).

Plant Select® row trials were conducted at Colorado State University and Chatfield Denver Botanic Gardens, in 2015. Thirty different taxa were evaluated by various Plant Select® personnel and data recorded throughout the growing season for flowering, overall plant performance and potential for self-seeding. Industry personnel annually view and evaluate the trials at both sites.

Ongoing Research

Research defining irrigation effects on growth, stress, visual quality and evapotranspiration of ornamental grasses continued during the 2015 growing season. Three species of ornamental grasses were evaluated, including; *Panicum virgatum* 'Rotstrahlbusch' (switch grass); *Schizachyrium scoparium* 'Blaze' (Blaze Little Bluestem) and *Calamagrostis brachytricha* (Korean Feather Reed Grass). These three grass cultivars were grown under four irrigation regimens (0%, 25%, 50% and 100% evapotranspiration replacement) and evaluated for ornamental quality and various stress parameters. Plants in the 0% treatment were smaller and not considered visually suitable for landscape use. In the 25% treatment, all three cultivars performed equivalent to their counterparts in the 50% and 100% treatments for all measured variables. Plants in the 25% mini-lysimeter study were more stressed than the 50% or 100% treatments during periods of drought, however, these plants were considered visually suitable for landscape use. This suggest that as long as ornamental grasses are kept on a strict weekly regimen of 25% ET_0 and are never exposed to periods of drought, they will be physiologically as well as aesthetically usable in landscape situations.

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Shepherdia × utahensis **performance in an irrigated demonstration garden in Reno, NV**

Heidi Kratsch
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Introduction

An ideal shrub for irrigated home and commercial landscapes in the high-desert climate of northern Nevada would be tolerant of intense natural and reflected light, hot summers, cold winters and poorly developed rocky soils. Although tolerant of periods with no moisture, it should also thrive with the consistent, shallow irrigation typical in an urban setting.

Shepherdia rotundifolia (roundleaf buffaloberry) plants have an attractive rounded form with ovate, pubescent, silver-green leaves (Sriladda et al., 2014). In their natural habitat, plants exhibit either an upright or a recumbent form, in which case they often are seen cascading off canyon walls and rocky slopes. As attractive as they are, roundleaf buffaloberry plants are also extremely drought-tolerant. Unfortunately, they have been found to be short-lived under cultivated conditions, often succumbing to conditions associated with over-watering.

Shepherdia argentea (silver buffaloberry) is a riparian shrub species that is thorny and thicket-forming in its natural environment (Sriladda et al., in review). It has narrow silver-green leaves and bright red berries in late summer. It has limited drought tolerance but does survive periods of reduced water availability; it thrives in wet, water-logged soils. Easy to propagate and with good post-transplant survival, it is used in naturalized native plant landscapes in urban sites but does not have the ornamental appeal that roundleaf buffaloberry holds.

Shepherdia × *utahensis* Sriladda, Kratsch & Kjelgren (Sriladda et al., in review) (buffaloberry hybrid) is a man-made hybrid between the Colorado Plateau endemic *S. rotundifolia* roundleaf buffaloberry and the U.S. western riparian *S. argentea* silver buffaloberry. It was created by hand-crossing male roundleaf buffaloberry plants with female silver buffaloberry plants in their native habitat. Successful hybridization was confirmed by AFLP-PCR (Sriladda et al., in review). The hybrids carry the desirable leaf morphological characteristics of roundleaf buffaloberry, including their evergreen nature. Physiological responses appear to be more similar to that of silver buffaloberry (Sriladda et al., in review), making them a potentially attractive candidate for high-desert urban landscapes.

Preliminary results of the buffaloberry hybrid garden trials showed excellent survival when transplanted as cuttings (Kratsch, 2014). Here we report on second-year landscape performance of the buffaloberry hybrid plants.

Methods

In July 2014, we installed nine buffaloberry hybrid plants, propagated from cuttings, in a demonstration garden on the west side of the University of Nevada Cooperative Extension office in Washoe County. Mean cutting length × width (mean of two perpendicular widths) at the time of transplant was 16.5 cm × 4 cm, with no branching. During the establishment period, plants were irrigated with drip emitters, and three staggered 12-inch wooden stakes were placed to the west of each plant to prevent wilting from late afternoon sun and reflected heat. Irrigation was set to 30 minutes three times per week. During the 2015 growing season, irrigation was tapered gradually to a final schedule of 60 minutes once per week, or as needed. In November 2015, plant height and width (mean of two perpendicular widths) were recorded Table 1. Plant size was also recorded and represents the product of the height and two perpendicular widths.

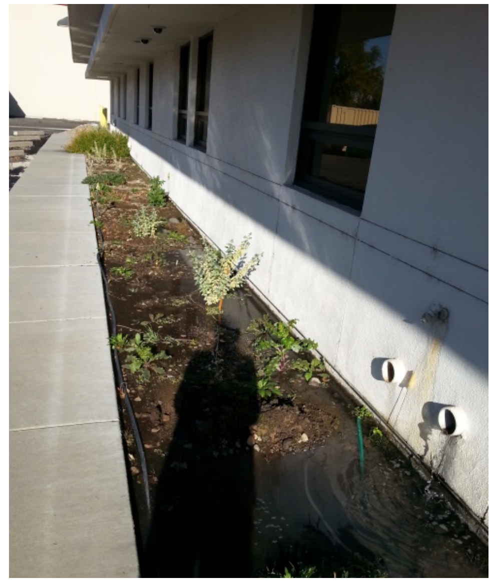

Figure 1. Flooding of the demonstration garden bed due to a break in the wall faucet in late summer 2015. Flooding was most acute within a meter on either side of the wall faucet. Soil moisture levels were elevated in a decreasing gradient with increasing distance from the irrigation water source.

Results and discussion

All nine buffaloberry hybrid plants survived transplanting in 2014, despite being planted in the heat of summer, with no visible signs of drought stress (Kratsch 2014). All but one plant had at least an inch of top growth and started forming side branches by fall 2014. We noted bronzing of some of the foliage after two months in the ground. It has been hypothesized that this bronzing under cultivated conditions is a nutrient deficiency (Sriladda et al., in review). We also noted the presence of spider mite on plants in our demonstration garden (Kratsch, 2014), which causes similar symptoms; however, the spider mites could have been a secondary pest. No definitive cause for the foliar bronzing can be confirmed at this time.

In early spring 2015, two plants succumbed to “landscaper blight”; they were inadvertently pulled as weeds. By September 2015, plants had grown an average of 32.2 cm in height, with a range from 7.5 cm to 51.5 cm (Table 1). They increased in width an average of 34.6 cm, with a range from 7 cm to 89 cm. Plant size ranged from 10.1 × 1,000 cm^3 to 588.1 × 1,000 cm^3, with a mean size of 132.5 × 1,000 cm^3.

In September 2015, a break was discovered in the pipes leading to the wall faucet which supplied our irrigation system. It is unknown exactly when the break occurred, but it resulted in persistent flooding of the planted area in the vicinity of the faucet (Figure 1). A decreasing gradient of soil moisture levels with increasing distance from the source of the break was noted. This affected growth of the buffaloberry hybrid plants (Table 1). Plants closer to the break were shorter and smaller overall, with less branching (Table 1; Figure 2, A and B). The largest plant (Figure 2, G) was furthest from the water source and achieved some degree of protection due to the presence of a thick stand of Red Rocks penstemon (*Penstemon* × *mexicali* ‘Red Rocks’), a long-blooming vigorous hybrid, between the specimen and the downspouts.

Some effect on growth could also have been caused by the presence of downspouts that drained moisture from the roof of the building directly into the garden area. Two downspouts are within a meter on either side of the irrigation water faucet (Figure 1); they likely affected specimens A and B (Figure 2). Two more are located within a meter of specimens E and F.

Buffaloberry is an actinorhizal species, forming a nitrogen-fixing association with the soil bacterium *Frankia* (Beddes and Kratsch, 2009). Formation and activity of nitrogen-fixing nodules resulting from this symbiotic association in alder, another actinorhizal species, is known to be affected by flooding (Kratsch and Graves, 2004a). Low root-zone oxygen levels are a direct result of flooding, and this low-oxygen stress affects nodule formation and activity (Kratsch and Graves, 2005). Plant growth is directly related to nodule activity in the absence of fertilizer application in alder (Beddes and Kratsch, 2010), and nitrogen fixation by way of symbiotic nodule activity is proposed to be a mechanism of stress avoidance in actinorhizal species (Kratsch and Graves, 2004b). Therefore, we hypothesize that growth retardation and leaf discoloration of our buffaloberry hybrids may have been due to stress related to flood-induced low soil oxygen levels on nodule formation and activity. Future work should investigate whether hybrid buffaloberry plants form nodules, and the degree to which cultivated conditions may induce stress that effects nodule formation and activity.

Table 1. *Shepherdia* × *utahensis* growth after 17 months in a demonstration garden in Reno, NV. Measurements were recorded in September 2015.

Specimen[z]	Height (cm)	Width (cm)[y]	Plant Size (1,000 cm^3)[x]
A	24	20.5	10.1
B	37	11	4.4
C	67	50	163.2
D	36	28	28.2
E	55	25	34.3
F	54	43	99.4
G	68	93	588.1

[z] Letters correspond to photos of specimens shown in Figure 1. Each letter represents one specimen.
[y] Width was measured in two dimensions, perpendicular to one another; the mean is reported.
[x] Plant size is the product of the height and two perpendicular widths.

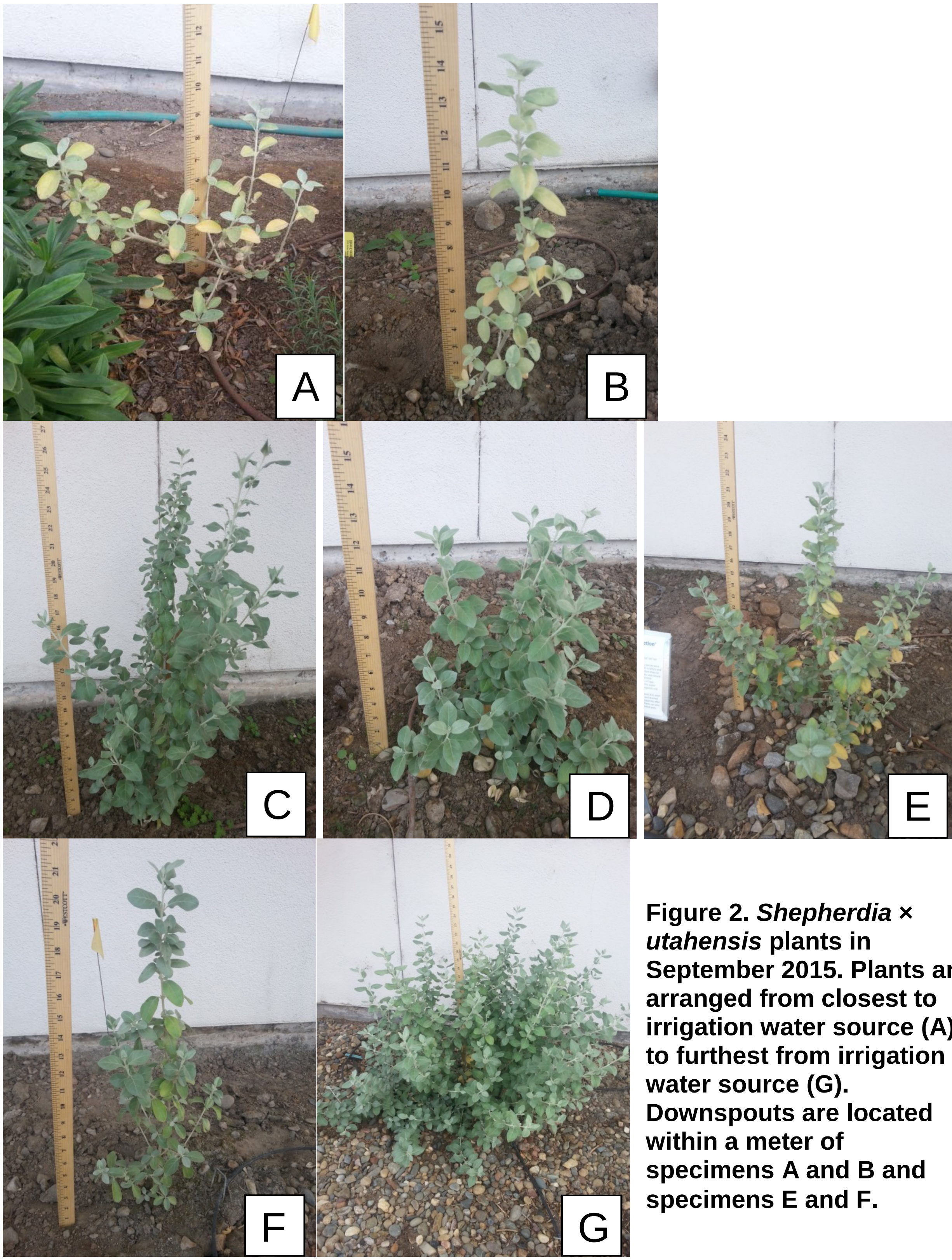

Figure 2. *Shepherdia* × *utahensis* plants in September 2015. Plants are arranged from closest to irrigation water source (A) to furthest from irrigation water source (G). Downspouts are located within a meter of specimens A and B and specimens E and F.

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Wildflower Meadow Establishment Using a Grass-First Strategy

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Wildflower meadows are used for roadside beautification, reclamation of disturbed urban public lands, habitat establishment in parks and golf courses, and improvement of minimally-managed private property (Delaney et al. 2000); Weaner 2012; Weston 1990). Potential benefits from a successful wildflower meadow planting are numerous and include, soil stabilization, improved aesthetics, pollutant entrapment, habitat improvement for birds, small mammals and pollinators, reduced maintenance costs, species conservation, and opportunities for education (Aldrich 2002; Delaney et. al 2000).

Common perception is that establishment of a natural-looking, functional wildflower meadow is as simple as tilling a plot of ground, scattering some seeds, and letting nature take its course. This approach is a recipe for disaster because it does not account for competition from aggressive annual weeds. Inadequate weed control during establishment is the most common contributor to failure of new meadow plantings (Aldrich 2002).

Once established, meadows can become invasion-resistant and have a chance of being successful in the long term (Blumenthal et. al 2003). Managing weed competition in the establishment year appears to be the key to immediate and long-term success. Appreciation of this principle suggests a potential mechanism for successful establishment of wildflower meadows under conditions of a heavy annual weed seed bank; the idea being to pre-establish grasses and use proven turf weed-control methods. This procedure may effectively reduce the pressure of competition from pioneer weed species.

Research objectives for this study were to determine the efficacy of a grass-first strategy for wildflower meadow establishment, meaning grass components planted first, followed by mowing and herbicide treatments for initial weed control, and finalized by seeding or transplanting wildflowers into the established grass stands and to compare transplanting and direct seeding as tools to optimize species establishment and aesthetic value in a wildflower meadow.

Study Procedures

The meadow establishment study was conducted during the years 2013 through 2015 at the University of Idaho’s Aberdeen Research and Extension Center at Aberdeen, Idaho. The study field was located on the site of an old abandoned homestead. Native grasses and wildflowers were absent from the site, the soil weed seed bank high and persistent, and annual weed pressure historically high and consistent.

Seeds of 17 adapted and potentially suitable native plant species, 5 grasses and 12 wildflowers (Table 1), were selected for the study and purchased from Western Native Seed (Coaldale, CO). NRCS Las Lunas Plant Materials Center recommendations for seeding grasses in semi-arid ecoregions was used as a basis for seeding rates used in the study (Dreesen, no publication year indicated). Seeds were combined to create two separate seed mixes, one for grasses and the other for wildflowers. Calculations for the mixes were based on target total seeding rates of 50 pure live seed (PLS) per sq ft for the 5 combined grass species and 48 PLS per sq ft for the combined 12 wildflower species.

Transplants for the 12 wildflower species used in the study were produced in a greenhouse at the Aberdeen R & E Center. Seeds of western larkspur and the two penstemon species were stratified for 3 weeks prior to planting. Seeds of all 12 species were seeded into flats about the middle of July. Transplants were between 3 cm (1.2 in) and 10 cm (3.9 in) tall, depending on species, at the time they were transplanted to the field.

Plots were arranged in a randomized complete block design with 3 replications. Individual main plots were (400 sq ft) with dimensions of 20 ft x 20 ft.

The study consisted of eight treatments:

1: *Common-practice Control:* Designed to duplicate typical meadow establishment procedures. Grasses and wildflower seeded in June. No weed control methods employed.

2. *Hand-Weeded Control:* Designed for optimal establishment conditions. Grasses seeded in June. Weekly hand-weeding. Wildflowers seeded into grasses in August.
3. *Mowed & Seeded:* Designed to test mowing for weed control plus seeding for wildflower establishment. Grasses seeded in June. Mowed weekly at 2.5 in. Wildflowers seeded into grasses/weeds in August.
4. *Mowed & Transplanted:* Designed to test mowing for weed control plus transplanting for wildflower establishment. Grasses seeded in June. Mowed weekly at 2.5 in. Wildflowers transplanted into grasses/weeds in August.
5. *2,4-D Herbicide & Seeded:* Designed to test a single 2,4-D herbicide application for weed control plus seeding for wildflower establishment. Grass seeded in June. 2,4-D applied in July. Wildflowers seeded into grasses/weeds in August.
6. *2,4-D Herbicide & Transplanted:* Designed to test a single 2,4-D herbicide application for weed control plus transplanting for wildflower establishment. Grass seeded in June. 2,4-D applied in July. Wildflowers seeded into grasses/weeds in August.
7. *Trimec® Herbicide & Seeded:* Designed to test a single Trimec® herbicide application for weed control plus seeding for wildflower establishment. Grasses seeded in June. Trimec® applied in July. Wildflowers seeded into grasses/weeds in August.
8. *Trimec® Herbicide & Transplanted:* Designed to test a single Trimec® herbicide application for weed control plus transplanting for wildflower establishment. Grasses seeded in June. Trimec® applied in July. Wildflowers transplanted into grasses/weeds in August.

Mowing treatments started when the vegetation in the plots was about 4 in tall. Plots were mowed twice per week throughout the treatment period. Single applications of 2,4-D and Trimec® herbicides were made July 26 when vegetation in the plots was about 4 in tall. Application rates were 2 pints/A for the 2,4-D and 9.1 7.8 pints/A for the Trimec®.

Grass and wildflower components in the common-practice control and grass components for the remainder of the treatments were broadcast-seeded (raked to a depth of 0.25 in) on 28 Jun 2013. Plots were sprinkler irrigated until emergence. During the summer of 2013, irrigation was continued through the weed control phase with weekly water applications of approximately 0.5 in.

In the seeded plots, wildflower species were planted into the established stands of grasses (some weeds present) on 28 Aug 2013. Seeds were broadcast by hand and the plots raked carefully to limit damage to established plants. On the same date, greenhouse-grown potted wildflowers were planted into the transplanted plots. A total of 95 wildflower transplants were placed into each plot, considerably fewer than the approximately 19,200 live seeds scattered into each seeded plot.

Table 1. Common names, scientific names, and seeding rates for 17 native grass and wildflower species used as components in a meadow seed mix.

Common Name	Scientific Name	Seeding Rate (PLS/sq ft)
Grasses		
Idaho fescue	*Festuca idahoensis*	10
Indian ricegrass	*Achnatherum hymenoides*	10
Big bluegrass	*Poa secunda*	10
Slender wheatgrass	*Elymus trachycaulus*	10
Tufted hairgrass	*Deschampsia caespitosa*	10
Wildflowers		
Yarrow	*Achillea millefolium*	4
Pacific aster	*Symphyotrichum chilense*	4
Purple prairie clover	*Dalea purpurea*	4
Western larkspur	*Delphinium x occidentale*	4
James' buckwheat	*Eriogonum jamesii*	4
Blanketflower	*Gaillardia aristata*	4
Blue flax	*Linum lewisii*	4
Rocky Mountain penstemon	*Penstemon strictus*	4
Firecracker penstemon	*Penstemon eatonii*	4
Black-eyed Susan	*Rudbeckia hirta*	4
Mexican hat	*Ratibida columnifera* [Asteraceae]	4
Munro's globemallow	*Sphaeralcea munroana*	4

Determination of the number of transplants to deploy was based on our interpretation of practicality considering labor and expense. After seeding and

Broadcast seeding and transplanting of wildflowers into established grass plots in August, 2013

transplanting, plots were irrigated once per day for the next 10 days after which the summer irrigation schedule was resumed until mid-October.

One and two years after establishment (2014 and 2015), plant counts averaged for two randomly positioned meter-square quadrats were taken for each plot to provide an estimate of species density - with separate counts for grasses, wildflowers, and total weeds. Final data collection in 2015 included a subjective aesthetic value score and whole-plot counts of wildflowers, by species.

Statistical analysis was completed in two steps. First, analysis of variance was completed for a data set that included the two control treatments and the 3 seeded weed control treatments in order to determine the statistical and biological significance of the mowing, 2,4-D, and Trimec® treatments. Next, control treatments were dropped from the data set and a factorial analysis of variance completed to explore the treatment effects and interactions of the weed control and planting method treatments. All analyses were completed using PROC ANOVA in the SAS statistical program. Means separations were made using Fischer's least significant difference test (LSD).

Meadow establishment plots in October 2013, two months after seeding and transplanting of wildflowers.

Findings

Visual inspections in mid-July, following the June seeding procedures, revealed consistent emergence of meadow component seedlings. In the common-practice control plots, most grass and wildflower species emerged to produce a uniform stand of meadow component plants. At the same time, annual weeds emerged in very high numbers and immediately began competing with the meadow species seedlings.

Wildflowers were also successfully established in August after being either seeded or transplanted into stands of established grasses.

In 2014, there were significant treatment effects for grass (*Prob.>F*<0.01) and weed (*Prob.>F*<.01) density, but the treatment effect on wildflower density (*Prob.>F*=0.18) was not statistically significant (Table 2). This last result was likely due to the presence of noise in the data created by a lack of uniformity in wildflower distribution that our sampling methods did not resolve. All of the grass-first weed control treatments had a positive impact on weed control. Weed density in the common-practice control was 1,145 per sq m. Weed density in all other treatments ranged from 11 to 45 weeds per sq m and was not significantly different from one treatment to another. The highest density of grasses occurred in the Trimec® treatment, while the other treated plots were similar, but all were significantly higher than the common-practice control.

Table 2. Density of grasses, wildflowers, and weeds in seeded treatments on 24 Jun 2014 and 17 Jul 2015. All meadow species in the common-practice control were seeded as a mix on 28 Jun 2013. In other treatments, grass components were seeded on 28 June 2013 and wildflower components planted after application of weed control on 28 Aug 2013. Aesthetic value was rated only in 2015 on a subjective 1 to 10 scale with 10=best.

Treatment	**Grasses per sq m**	**Wildflowers per sq m**	**Weeds per sq m**	**Aesthetic Rating**
2014				
Common-practice control	1	1	1,145	-
Hand-weeded control	14	3	11	-
Mowed - Seeded	14	3	45	-
2,4-D - Seeded	18	4	36	-
Trimec® - Seeded	23	7	14	-
LSD (0.05)	8	NS	313	-
2015				
Common-practice control	0	1	545	1.8
Hand-weeded control	4	9	40	6.2
Mowed - Seeded	14	6	33	7.5
2,4-D - Seeded	14	5	16	7.2
Trimec® - Seeded	15	4	13	6.5
LSD (0.05)	8	NS	NS	3.6

In 2015, the average weed density in the common-practice control treatment was about half as high as in 2014 while the grass-first plots, on average, changed very little. Surprisingly, although the weed density in the common-practice control was many times higher than in the grass-first plots, there was no significant difference among treatments. Lack of significance seemed to be the result of experimental noise created by differential succession in the plots. Annual weed survival in many of the plots declined dramatically, while changing very little in others.

In 2015, an aesthetic value rating was added to data collection. This subjective rating was designed to reflect the inherent attractiveness of the established meadow in the case of each treatment. The highest aesthetic value scores (highest rating=10) were given to plots with few weeds, a visible balance between grasses and flowering wildflowers, and a pleasing palette of color. All of the grass-first treatments had higher aesthetic value ratings than the common-practice control. No significant differences existed among the treatments for which turf-appropriate weed control methods were applied.

As an additional step in evaluation, a factorial analysis was completed to increase sensitivity for detecting differences between the weed control methods and planting methods and to allow exploration of the interaction between these two variables (Table 3). No significant interactions were detected between weed control methods and

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Table 3. Density of grasses, wildflowers, and weeds as influenced by weed control method (mowing, 2,4-D. or Trimec®) and wildflower planting method (seeding or transplanting). Interaction between the two variables was insignificant at *P*=0.05. Aesthetic value was rated only in 2015 using a subjective rating scale of 1 to 10 with 10=best.

Treatment	Grasses per sq m	Wildflowers per sq m	Weeds per sq m	Aesthetic Rating
2014				
Weed control method				
Mowing	15.4	2.8	42.8	-
2,4-D	15.6	2.2	229.5	-
Trimec®	21.3	4.6	9.8	-
LSD (0.05)	NS	NS	NS	-
Planting method				
Seeding	18.2	4.7	31.5	-
Transplanting	16.7	1.7	156.6	-
LSD (0.05)	NS	1.9	NS	-
2015				
Weed control method				
Mowing	14.2	3.9	24.6	6.3
2,4-D	13.3	2.6	70.4	5.5
Trimec®	14.8	2.7	15.8	6.0
LSD (0.05)	NS	NS	NS	NS
Planting method				
Seeding	14.1	5.2	20.4	7.1
Transplanting	14.1	0.9	53.5	4.8
LSD (0.05)	NS	2.2	NS	1.3

planting methods for any of the variables measured. Weed, grass, and wildflower density was statistically similar across all weed control methods for both evaluation years. Planting method had no influence on grass or weed density. Wildflower density was significantly lower both years in the transplanted vs seeded treatments. Given the lower initial planting density in the transplanted plots, this was an expected result. Weed control method did not have a significant effect on the final aesthetic value rating, although planting method did. The lower number of wildflowers associated with fewer flowers and thus, color elements in the plots, resulted in a lower aesthetic value rating for the transplanted plots in comparison with the more attractive seeded plots.

Weed-infested common-practice control plot 2 years after establishment.

Summary

Successful establishment of a wildflower meadow was accomplished through the use of a grass-first protocol. The strategy employed a 3-step process, 1) spring planting of grass component species, 2) application of proven turf-appropriate weed control practices during the summer, and 3) early fall planting of wildflower component species into the established grasses. Each of the 3 employed weed control methods: mowing, application of 2,4-D, or application of Trimec®, resulted in successful meadow establishment under conditions of complete failure for a non-weeded, common-practice control. Fall transplanting of the wildflower components into established grasses was successful and proved a good method for meadow completion. Transplanted wildflowers were initially larger and more competitive than their seeded counterparts, and tended to bloom the first year. However, seeding resulted in a greater density of wildflowers and, ultimately, an overall more aesthetically pleasing mix of flowering plants and grasses.

The grass-first protocol should be a valuable tool for meadow

Mix of grasses and wildflowers after 2 years in a plot mowed for weed control with wildflowers broadcast-seeded.

establishment in urban and suburban sites where native plantings are desired for habitat development and beautification. The procedure was vetted under modestly controlled conditions where water and fertilizers were applied to optimize plant establishment and kick-start nutrient cycling. An assumption is made that providing enhanced establishment conditions and ongoing minimal inputs of water will be necessary in arid climates such as those found in southeast Idaho if a meadow is to provide displays of season-long color.

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Incorporation of Native Plants into a Greenhouse Production Course

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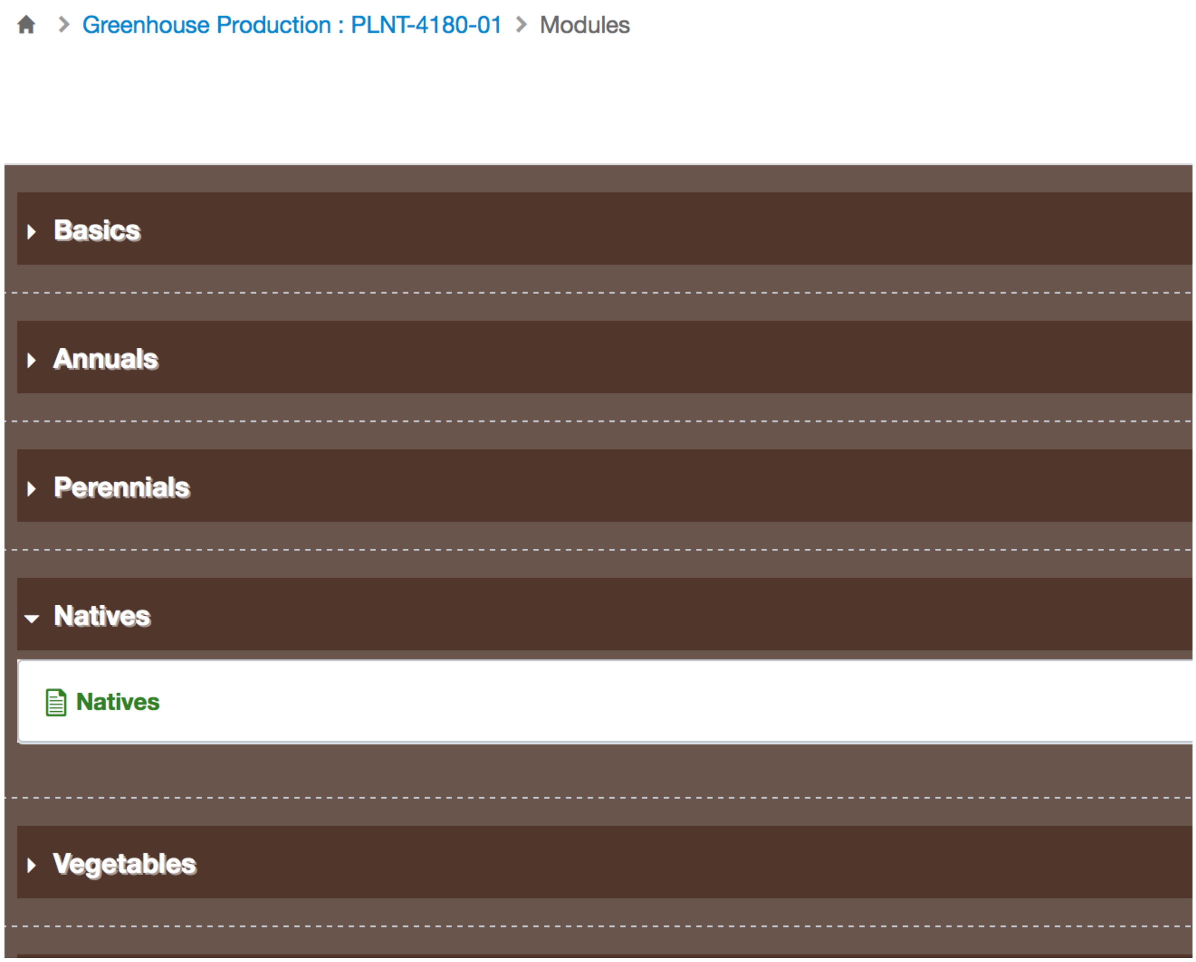
This year my presentation at our annual meeting highlighted ways in which native plants are discussed in one of the courses I teach, Greenhouse Crop Production (PLNT4180/5180). It is a 4-hour senior/graduate level course that meets for 4 hours one day a week. Using this format we are able to make several field trips to view different greenhouses and their production strategies, including production of native plants.

The course includes eight modules: Basics, Annuals, Perennials, Natives, Vegetables, Fresh Cuts, Potted Flowering Crops, and Foliage. Students, our potential future extension educators and researchers and WERA1013 members, discuss several different research articles in the Natives module.



The articles used for discussion in the Natives module are on the topics related to propagation of plants in the genera *Penstemon*, *Castilleja*, *Eriogonum*, and *Ligusticum*:

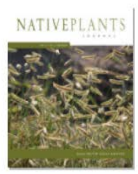
Penstemon discussion article for course PLNT4180/5180:

Evaluation of Penstemon as host for Castilleja in garden or landscape

Nelson, David A.

Native Plants Journal, Volume 6, Number 3, Fall 2005, pp. 254-262 (Article)

Published by Indiana University Press



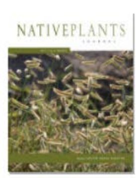
Castilleja discussion article for course PLNT4180/5180:

Propagation protocol for Indian paintbrush (Castilleja species)

Luna, Tara.

Native Plants Journal, Volume 6, Number 1, Spring 2005, pp. 62-68 (Article)

Published by Indiana University Press



Eriogonum discussion article for course PLNT4180/5180:

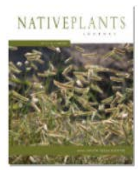
Project MUSE®
Today's Research. Tomorrow's Inspiration.

Seed production protocols for Anaphalis margaritacea, Eriophyllum lanatum, and Eriogonum umbellatum

Archibald, Colleen.

Native Plants Journal, Volume 7, Number 1, Spring 2006, pp. 47-51 (Article)

Published by Indiana University Press



Ligusticum discussion article for course PLNT4180/5180:

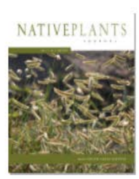
Project MUSE®
Today's Research. Tomorrow's Inspiration.

Oshá (Bear Root): Ligusticum porteri J.M. Coult. & Rose var. porteri

Bernadette Terrell
Anne Fennell

Native Plants Journal, Volume 10, Number 2, Summer 2009, pp. 110-117 (Article)

Published by Indiana University Press



Finally, students read and discuss a general article on student awareness of and interest in native wildflowers (HortTechnology 20(2) April 2010):

Awareness of and Interest in Native Wildflowers among College Students in Plant-related Disciplines: A Case Study from Florida

Hector Eduardo Pérez[1,6], Carrie Reinhardt Adams[1], Michael E. Kane[1], Jeffrey G. Norcini[2,5], Glenn Acomb[3], and Claudia Larsen[1,4]

ADDITIONAL INDEX WORDS. attitudes, education, blindness, web-based survey

SUMMARY. Traditional college students do not fit the demographic profile of people who are driving increased sales in gardening and landscaping or the use of native wildflowers. However, today's college students, especially those in plant-related disciplines, may be making future decisions regarding the use of native wildflowers for various applications. Many college students may be unaware of or disinterested in native wildflowers. We used a web-based survey to gauge awareness and interest of native wildflowers in Florida college students enrolled in plant-related disciplines. While students have a generally low awareness of native wildflowers, they expressed high levels of interest in learning more about the identification or cultivation of these species, seeing wildflowers, particularly on their campuses, and using wildflowers in different settings. Students were also interested in purchasing native wildflower seeds or finished plants from local retailers rather than through the Internet. We used student responses from this study to discuss education and marketing opportunities toward native wildflowers.

In an interesting evolution, I have observed that students today are far more interested in greenhouse edible crops grown than they are in ornamentals, including natives. With the emphasis in the last few years on local food production, students are looking to produce their own fruits and vegetables in the greenhouse, rather than traditional annuals, perennials, holiday crops, etc.

Propagating Singleleaf Ash (*Fraxinus anomala*): A Proof of Concept

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Department of Plant, Soils, and Climate

Introduction

Singleleaf ash (*Fraxinus anomala*) is a large, multi-branched shrub or small tree native to the Southwestern United States. In Utah, it occurs throughout the Colorado Plateau, as far north as the Uintah Basin, and west into Washington County. It is distinguished from other ash trees by its small size and tendency to produce simple leaves - unless growing under very favorable conditions. The leaves are an attractive yellow in the autumn. It is a very tough and resilient tree and occurs naturally in very harsh environments. As with other ashes it produces a single-seeded samara in clusters. Unlike other ashes, it has a complex stratification requirement for germination. The stems are four-sided and the wood is soft, yet brittle and can be easily damaged by mechanical injury. The biggest concern and unknown at this time is whether or not it is susceptible to the invasive emerald ash borer (*Agrilus planipennis*), a pest now on the borders of Utah. All comments and recommendations in this manuscript should be tempered by the risk of loss of this plant due to this borer.

There is apparently a great deal of diversity in the native populations of *F. anomala*, though it is often difficult to determine if differences are genetic of phenotypic. Our experience growing this species indicates that even when water-stressed to the point of leaf senescence it will re-leaf when conditions become favorable. Its resilience and drought tolerance speak to its potential as a good selection for water conserving landscapes. Use in landscape applications would be enhanced through selection of superior clones with characteristics such as dark bark, intense fall color, desirable size, and superior form. Selection of superior plants is contingent on being able to successfully propagate the plant vegetatively in a commercially feasible manner.

Propagation by Cuttings.

1. Cutting propagation using Nearing frames

As reported in the 2014 WERA1013 Proceedings, an experiment was completed in the summer of 2014 comparing propagation of singleleaf ash in either Nearing frame or greenhouse intermittent mist propagation systems. In summary, the percent rooting (28 and 25) and number of roots per cutting (2.5 and 2.3) were similar in greenhouse and Nearing frame environments, respectively, after 35 days. Extending the length of rooting time to 49 days resulted in 50% rooting for those in the Nearing frame and 41% for those in the greenhouse. At the end of 35 days, the cuttings in the greenhouse had better leaf color and that might account for the greater amount of late rooting. While 50% rooting is not at a level to be desired, it does demonstrate that this species can be rooted although there is a need for improved efficiency.

2. Cutting propagation of wild-collected plants

In a follow-up experiment, determination of the potential for rooting of wild-collected cuttings was evaluated in 2014. Cuttings were selected from several parent plants located in Wayne County, Utah during the week of June 23, 2014. Cuttings were wrapped in moist newsprint, placed in plastic bags, and held in a cooler on ice until placed in 4°C storage. On June 26, cuttings were trimmed, wounded with a one cm flat scrape at the stem base, dipped in 2000 ppm IBA/1000 ppm NAA as Dip 'N Grow in 25% ethanol for 5 seconds. Cuttings were stuck in 4:1 perlite:peat v/v substrate, drenched with Aliette® fungicide and held under a Phytotronics® controlled intermittent mist system held at a VPD setting of 30. There were a total of 12 accessions tested and the number of cuttings per accession ranged from 5 to 20 with a total of 131 cuttings stuck. Cuttings were evaluated after 4.5 weeks on July 28, 2014. Five rooted cuttings were removed while the remaining cuttings were dipped in water and then in 3000 ppm IBA talc (Hormodin® #2) and placed back on the bench. After three more weeks, all cuttings were evaluated for rooting.

Of the 13 wild accessions collected, all but three rooted as cuttings. Overall 46% of the cuttings rooted. The highest percentage was 85% with accessions 11 and 5, while the poorest was 0% with accessions 2 (5 cuttings), 7 (9 cuttings), and 8 (2 cuttings) (Fig. 1).

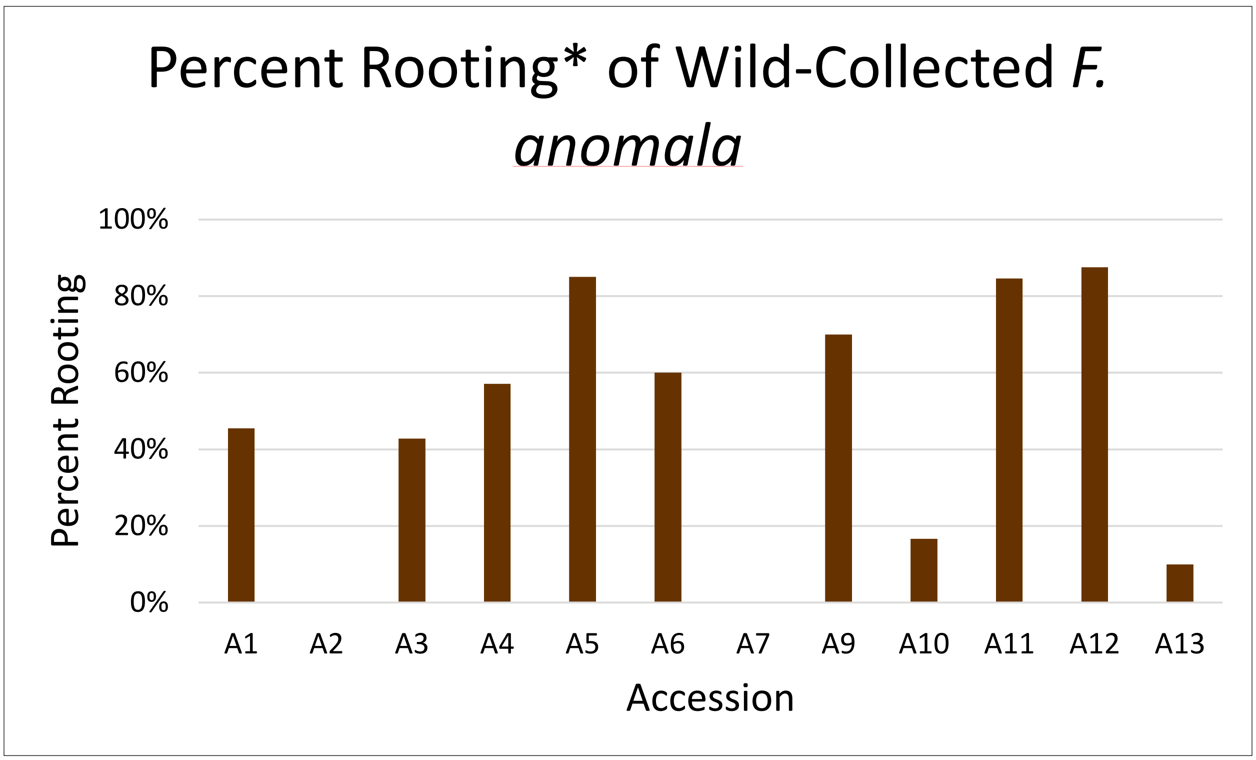

Figure 1. Rooting of wild-collected accessions of *F. anomala*. Cuttings were treated with 2000/1000 ppm IBA/NAA and stuck on 26 June 2014. After 32 days rooted cuttings were transplanted, the remainder were treated with Hormodin® 2 and re-stuck. Final harvest was after 54 days. *Number of cuttings per accession ranged from 5-20.

This experiment demonstrates that even with wild plant material, there is potential for rooting of *F. anomala* cuttings. While we did not record supporting data, it is of value to note that rooted cuttings easily break bud and begin growing again. This is in stark contrast to cuttings from trees such as bigtooth maple (*Acer grandidentatum*) that will not break bud until chilled. This tendency to resume growth results in greater survival of cuttings in general.

Propagation by Budding

1. Self-budding of *F. anomala*

As a backup to propagation by cuttings, we also evaluated the potential for budding wild *F. anomala* scion material to field grown stock plants. A preliminary experiment was completed on August 14, 2013 by self-budding (taking buds from a tree and grafting them back into the same tree) 14 buds on to a single nursery-grown tree under optimum conditions. Budding was repeated on August 15 on a separate tree using 16 buds. Budding was done before 8:30 AM with scion wood being removed from the tree, leaf blades excised, and immediately placed elsewhere on the plant. Budding methods were evenly divided between chip and T-buds. Budding was done using current season's wood for both the scion and stock. For chip budding, it was easy to prepare the receiving site in the stock by cutting into an internode. Preparing the bud was more difficult since the wood was brittle and appeared to be denser in the region of the vascular traces under the bud. Both of which led to a tendency for the wood to split during cutting. In the case of T-buds, they require a wide horizontal cut in the stock to allow the bark to lift without splitting. T-budding was easiest to perform by using scion wood that was significantly smaller than the stock, removing all wood from beneath the bud, and by using the tip of a knife blade to gently drag the excised bud under the flaps of the T without lifting them any more than necessary.

Bud success was determined by observed bud break on May 7, 2014. Results showed that 87% of chip buds and 60% of T-buds were successful. Further, the successful chip buds appeared much healthier than the T-buds.

2. Budding of wild-collected scions to field stock

The ability to graft wild *F. anomala* buds on a nursery-grown rootstock was determined using scion material collected from Wayne and Emery Counties of Utah. Scion wood was collected and wrapped in moist newsprint, placed in a plastic bag, and held in a cooler on ice until placed in a cooler at 4°C on the afternoon of June 25, 2014.

Chip budding was done on current and second season's wood of nursery-grown trees approximately 4 years old. The stock was very soft and easily cut in preparation for the buds. In contrast, the wild scion material seemed drier and was much harder to cut. A variable number of buds from each of 13 different accessions were grafted onto three different stock plants on June 26-27, 2014.

Results of this experiment indicated an overall success rate of 51% (Fig. 2). The ability to judge success as a group and on an individual accession level was hampered by loss of labels due to wind, and injury to shoots by mule deer breaking branches with their antlers. That being said, some accessions had success ratios as high as 5/5 while others were as low as 0/3 or 1/5.

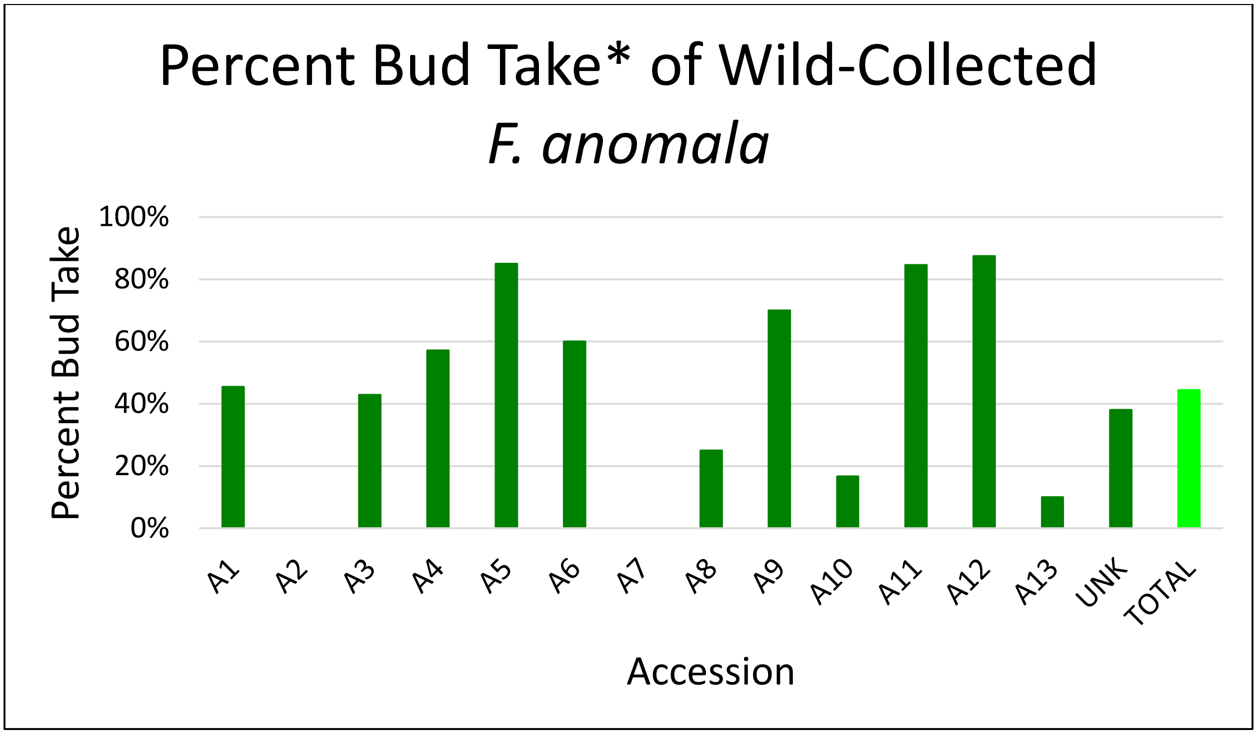

Figure 2. Percent bud take of wild-collected scion wood of *Fraxinus anomala*. *Number of buds ranged from 1 to 6 with 13 categorized as unknown accessions. Budding was done on June 26-27, 2014 and evaluated on May 4, 2015.

It is apparent that *F. anomala* can be successfully grafted using a chip bud technique. A success rate of 87% for chip budding using non-optimized, older plants as rootstocks rather than liners should be viewed as highly successful. The fact that we were able to get 51% success with wild scions should also be viewed as successful. There were several factors that could have contributed to the relatively low 51% success rate including collection of the scion wood from wild plants in naturally dry conditions, collection and budding in late June (typically successful budding would be done in late July to mid-August), and using scion wood of various ages (some of the wood could better be described as spur-like growth with very limited annual growth). It can further be concluded that collection and chip budding of scions from wild plant material is an effective way to bring such plants into a nursery environment. The long-term compatibility and success of grafted *F. anomala* has not been determined.

Propagation by Seed

1. Effect of accession and stratification treatment on germination.

Fraxinus anomala can also be propagated by seed, though it is purported to require warm followed by cold stratification. We conducted a preliminary experiment on seed propagation by collecting seed of four wild *F. anomala* accessions in Wayne County, Utah in November of 2014. Seeds were held at room temperature until the experiment was initiated on February 17, 2015. Seeds were randomly divided into lots of 100 seeds and four lots (one lot of each accession) planted in an 11 X 21 inch flat of 2:1 perlite:peat substrate. There were four replicate flats of each treatment for a total of 12 flats. The seeds were irrigated and those to be cold stratified were placed in a 4°C cooler and covered with aluminum foil. Those to be warm stratified were placed in a greenhouse at 18/16°C D/N temperatures without cover. Seedlings were given one of three treatments; 60 days warm stratification followed by 90 days cold stratification (60/90), 90 days warm stratification followed by 90 days cold stratification (90/90), and only cold stratification until seeds began to germinate (approximately 210 days) (210). After treatment, the seeds were placed in the greenhouse at 18/16°C D/N temperatures, 60% shade, 22°C bottom heat, and irrigated as needed. Germination was counted as seedlings emerged from the substrate. Seedling survival was counted as the number of viable seedlings present at six weeks.

Preliminary results (without statistical analysis) at one week showed accession 21 to be more capable of germination than the other accessions regardless of treatment (Fig. 3). Accessions 5, 11, and 12 showed poor germination in the 60/90 and 90/90 treatments. Better germination occurred in the 210 treatment. The highest germination percentage was only 25% which verifies the relative difficulty in getting this ash species to germinate. After six weeks, there were increased numbers of germinated seedlings with all accessions as compared to the percentage germinated at one week. Treatments 60/90 and 90/90 had greater increases, while the 210 treatment had reduced seedling numbers with all accessions except 12 (Fig. 4). Evidently the prolonged stratification (roughly seven months) of this treatment made these seedlings more susceptible to disease. Even at the highest level of germination, after six weeks only 35% of the seeds had resulted in surviving seedlings.

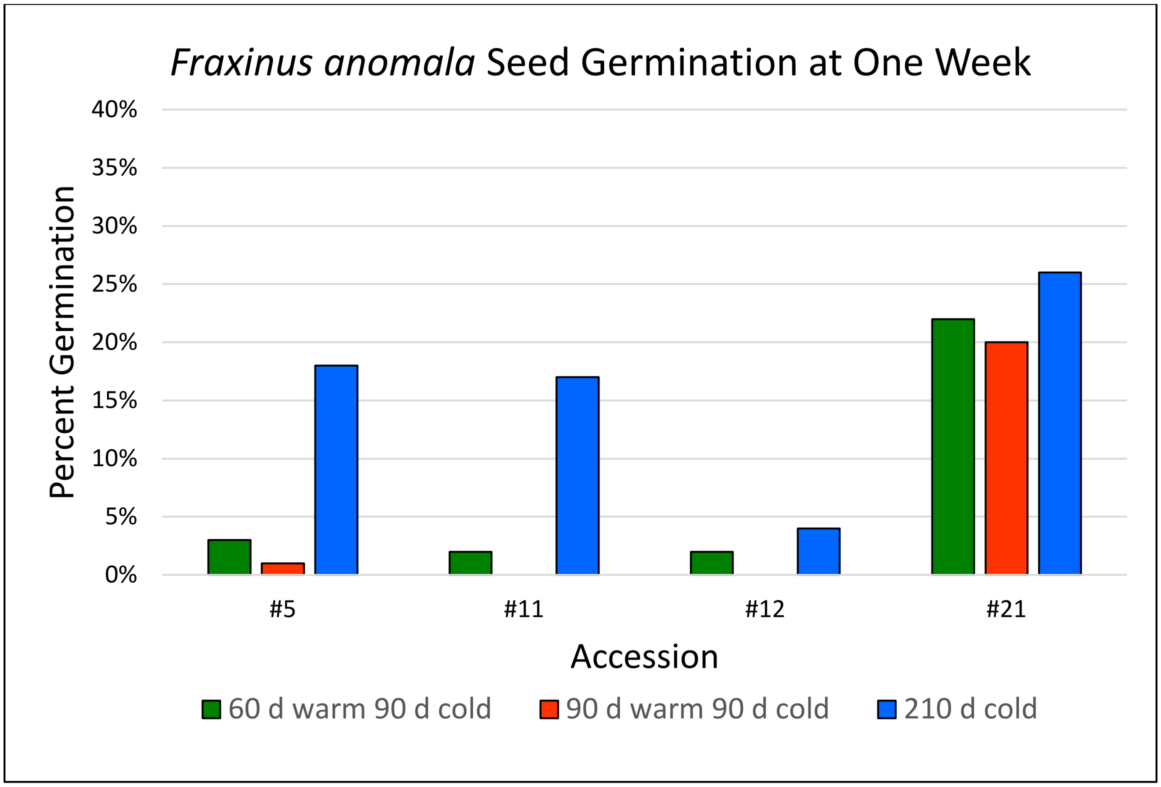

Figure 3a. The effect of different stratification treatments on germination of four separate accessions of *Fraxinus anomala* seed after one week.

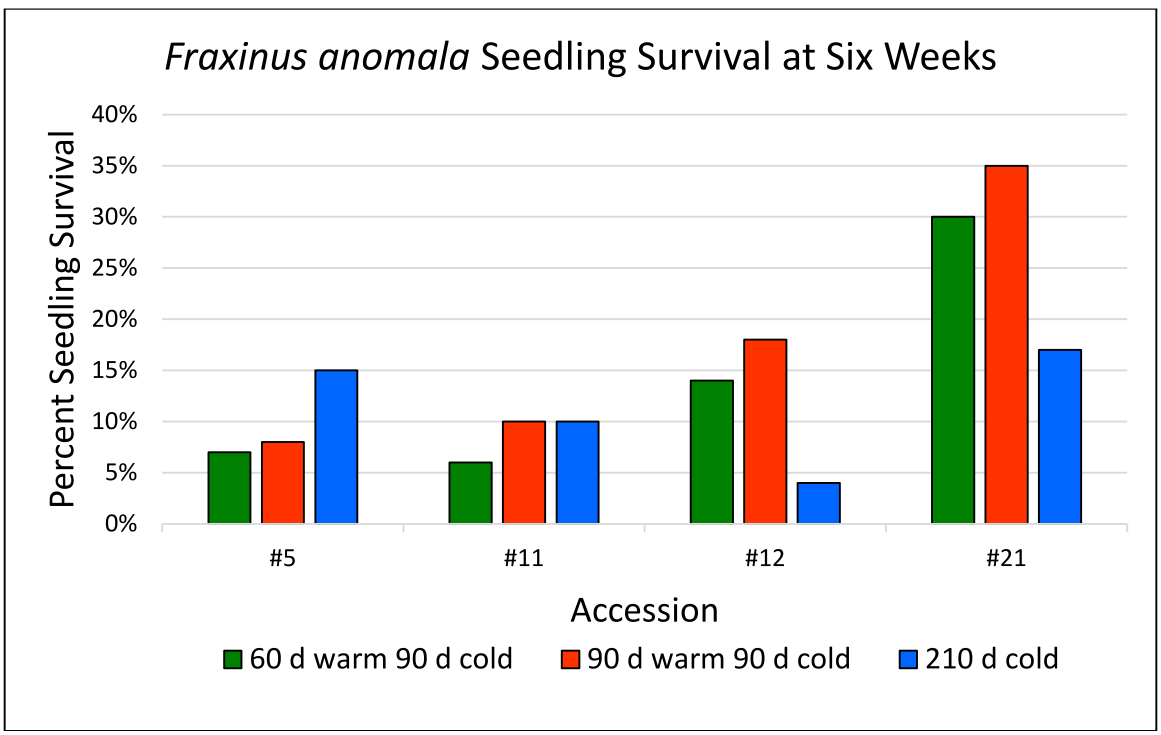

Figure 3b. The effect of different stratification treatments on seedling survival of *Fraxinus anomala* six weeks after being placed in a greenhouse environment.

Conclusions

In conclusion, we have found that singleleaf ash can be successfully propagated by seed, cuttings, or budding. We have also found that there appear to be different levels of propagation success depending on accession, with some being more prone to propagation while others are somewhat recalcitrant. The obvious next step in these various avenues of research would be to address methods for increasing efficiency of propagation. However, unless there is evidence proving that *Fraxinus anomala* is not susceptible to the emerald ash borer, then the value of such research is unknown at best and moot at worst.

The authors would like to acknowledge funding from the USDA Specialty Crop Block Grants program through the Utah Department of Agriculture and Food.

Autonomous Monitoring and Control of a Misting System for Plant Propagation using Leaf Wetness Sensors

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Abstract

A state-of-the art propagation system for control and automation of plant misting cycles in a greenhouse was constructed. The system incorporated leaf wetness sensors (LWS) to provide monitoring and control of the misting system. Corresponding temperature, relative humidity and solar irradiance sensors were used to continuously monitor greenhouse conditions. An initial study on the performance of the system was conducted on cuttings of *Shepherdia* × *utahensis* “Torrey” to evaluate system efficacy. Misting treatments were based on leaf wetness setpoints of 0.05, 0.10 and 0.15 mm. A monitoring screen was developed for real-time monitoring of the misting treatments that could be accessed online to provide remote supervision. *Shepherdia* cuttings were successfully rooted using the system with no significant differences due to LWS setpoints. While monitored data indicate that there are still issues such as uniformity of LWS that need to be improved, the results show that as a proof of concept, LWS can be used to both control and monitor intermittent mist.

Introduction

Intermittent mist systems for propagation of leafy cuttings are significantly different from irrigation systems used for optimizing plant production. Hartmann et al., (2011) described optimum light, water-humidity, and temperature conditions that are fundamental to successful propagation.

In most commercial greenhouses, misting systems are mainly controlled by temporal setpoints and require constant monitoring and adjustment (Jacobson et al., 1989). Temporal setpoints have their limitations and optimal environmental conditions are difficult for growers to maintain. Jacobson et al., (1989) developed an autonomous system for monitoring and controlling misting systems that incorporated environmental sensors connected to a controller (datalogger) to regulate misting cycles both daily and seasonally based on fluctuating environmental conditions. The system used three thermocouples, a relative humidity (RH) sensor and light sensor to operate solenoids connected to misting lines triggered by environmental setpoints programmed in the controller. The autonomous system proved to accurately monitor conditions and control them for optimum plant propagation; however programming software proved challenging.

Jacobsen et al., (1989) and several other studies proposed to develop prototypic greenhouses with sophisticated control systems for biological environments based on application of electronic software and hardware (Dickey and Toussaint, 1984; Hoshi and Kozai, 1984; Kok et al., 1986; Jones 1987). Their goals were to overcome limitations

imposed by manual controllers for perceived optimal frequency and duration of misting systems. These studies; however, did not measure leaf wetness.
Most studies associated with LWS have been used by plant pathologist, physiologists and entomologist to understand rates of infection by diseases, activity of insects and effectiveness of pesticides. Crook (2012) did use LWS as a means of monitoring mist systems in commercial greenhouses. However research on the use of LWS for controlling intermittent mist in plant propagation has not been extensively studied.

This study looks to update findings from Jacobsen et al., (1989) and Crook (2012) by monitoring and controlling misting systems with the use of LWS. We hypothesize that the LWS will better manage mist systems by more accurately controlling the amount of moisture on the leaf. We further hypothesize that the LWS will improve performance by supporting continuous monitoring of mist system performance.

Materials and Methods

The mist system was installed in a 6.3 by 7.5 m greenhouse with three benches and six misting environments (two per bench). Each environment was surrounded by Reemay® row cover material to reduce air movement and overspray. Each treatment also included four misters spaced roughly 0.6 m apart and on risers 0.66 m above the bench. The greenhouse environment was monitored using several environmental sensors. Solar radiation was monitored using two SP-110 pyranometers (Apogee Instruments, Logan, Utah). One sensor was placed in the rafters of the greenhouse and the other was placed on a table as a floating pyranometer that could be placed next to plants. Relative humidity (RH) and temperature were measured using a HMP 155 probe (Vaisala Corporation) and a HC2S3 probe (Campbell Scientific Inc.). Each instrument was placed on a table at plant level shielded by PVC (Figure 1). Two replications of each of three misting environments were established by placing a LWS (Figure 2) in each environment and randomly assigning them to one of three dry down thresholds (0.15, 0.10 and 0.05 mm leaf wetness depths). The LWS were set at slope of 10° with a cotton string 10 cm long hanging from the end to help wick away excess water adhering to the margin of the sensor. The basic output of the LWS is a number ranging from 0 to 500. These values are good at representing qualitatively high and low values of leaf wetness, however, the actual quantitative values in mm depth to establish the treatments required conversion equations to be added to the program and are similar to the equations used on the Environmental Observatory at Utah State University (see appendix). Sensors were connected to a CR1000 datalogger (Campbell Scientific Inc., Logan, Utah) and programed using CRBasicEditor in Loggernet programing software for contiuous monitoring of the system (See Appendix for program). Misting events were triggered by reduction in the depth of moisture on the LWS to the pre-set thresholds. Once the threshold was met, a mist event would occur for five seconds. Monitoring of misting treatments was achieved through the manufacturing of a display screen that showed misting cycles over a 24 hr period and real-time leaf wetness depths (Figure 3). This screen can be accessed online through the Crop Physiology Laboratory at Utah State University website (cpl.usu.edu) which allows for remote supervision of the system.

The effect of the LWS mist control on cutting propagation was evaluated using cuttings of *Shepherdia* × *utahensis* "Torrey". Terminal cuttings of field-grown plants were collected in early morning on August 12, 2015. Cuttings were held in plastic bags at 4°C until stuck later in the day. Cuttings were trimmed to approximately 10 cm and the leaves stripped from the bottom one or two nodes leaving 2-3 nodes with leaves at the tip. Cuttings were randomly assigned to one each of three treatments and then divided into two replicates with four groups of ten in each replicate. Cuttings were then wounded by scraping a strip of bark off the bottom 1 cm of the stem before dipping in water and then in Hormodin 1® (1000 ppm indolebutyric acid) to a depth covering the wound. Cuttings were stuck in Turface® in 5 x 5 x 7.5 cm containers, moved to the greenhouse and lightly irrigated. The mist system was set to run from 6:00 AM to 10:00 PM with supplemental light being supplied from 5:00-7:00 AM and 8:00-10:00 PM. Greenhouse temperature setpoints were 18/15.5°C D/N with 60% shade. Bottom heat at 22 ± 1°C was supplied in each environment and controlled by one sensor for both replications within treatments.

Cuttings were harvested on September 14, 2015. Plant measurements included: percent rooted cuttings, number of roots per cutting, and longest root per cutting. All data was analyzed for statistical differences between misting treatments in SAS (version 9.3; Cary, NC, USA) using PROC-GLIMMIX with a significance level set at $p = 0.05$.

Figure 1. Fabricated shield containing the HMP 155 and HC2S3 relative humidity sensors.

Figure 2. Mounting stand with leaf wetness sensor

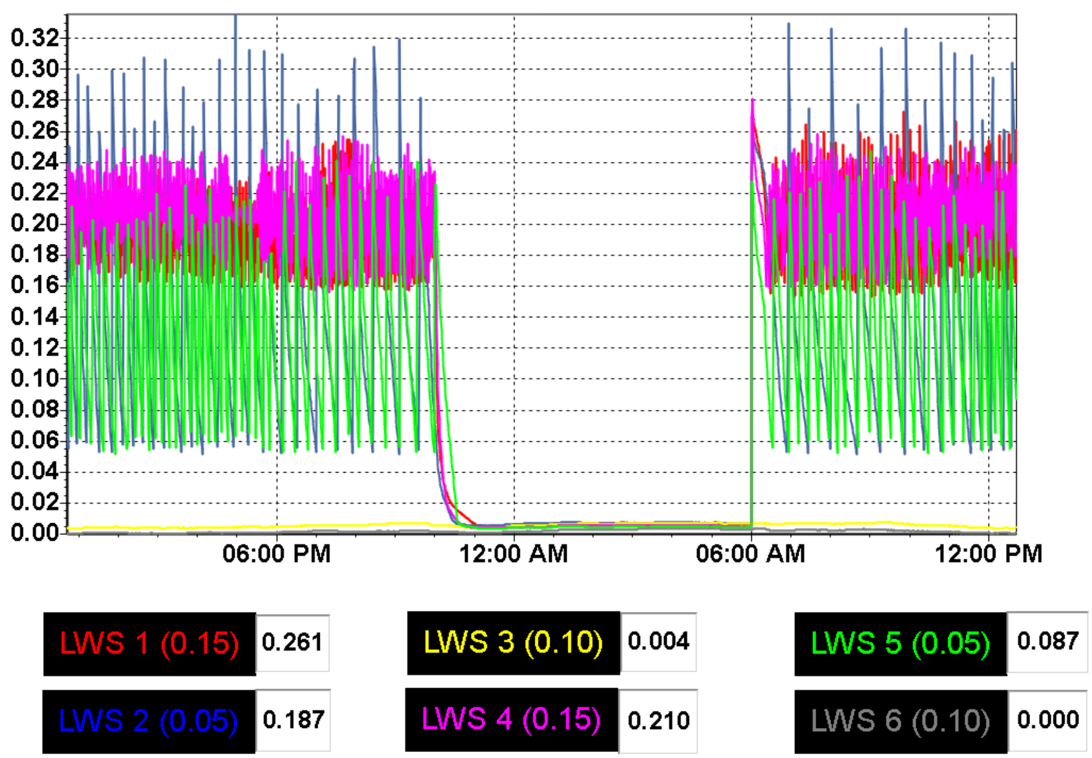

Figure 3. Display screen that can be accessed via cpl.usu.edu to monitor misting system including misting events and leaf wetness depths.

Results and Discussion

The monitoring screen indicated that the treatments were performing accurately and also provided indirect oversight for identifying any issues during the study.

The mist system was set to run from 6:00 AM to 10:00 PM (Figure 3). Supplemental lighting was also provided during the morning and evening hours to correspond with the misting period and insure long days.

Environmental conditions recorded throughout the study included temperature (Figure 4), RH (Figure 5) and light intensity (irradiance) (Figure 6). Greenhouse temperature and RH averaged 20.5°C and 63% respectively over the course of the study and all sensors. There were slight drifts and fluctuations attributable to the changing natural environmental conditions as seasonal changes progressed from summer to fall. Irradiance (Figure 6) was also consistent throughout the study.

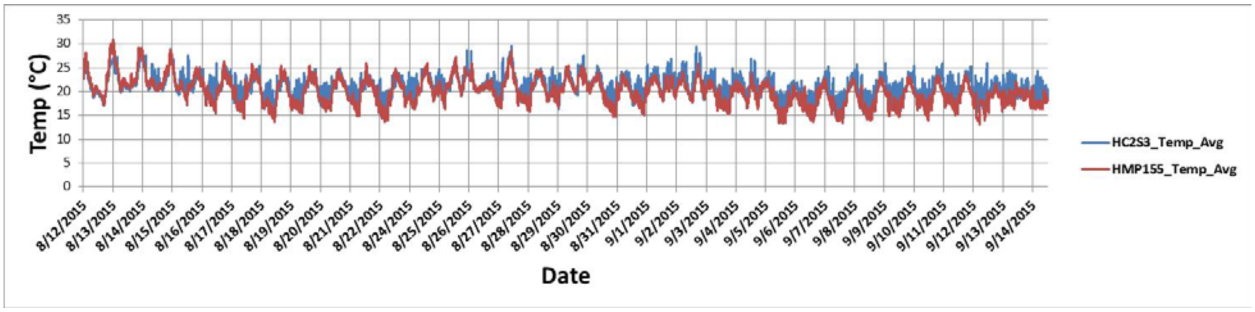

Figure 4. Temperature in degrees Celsius throughout the study for HMP 155 and HC2S3sensors.

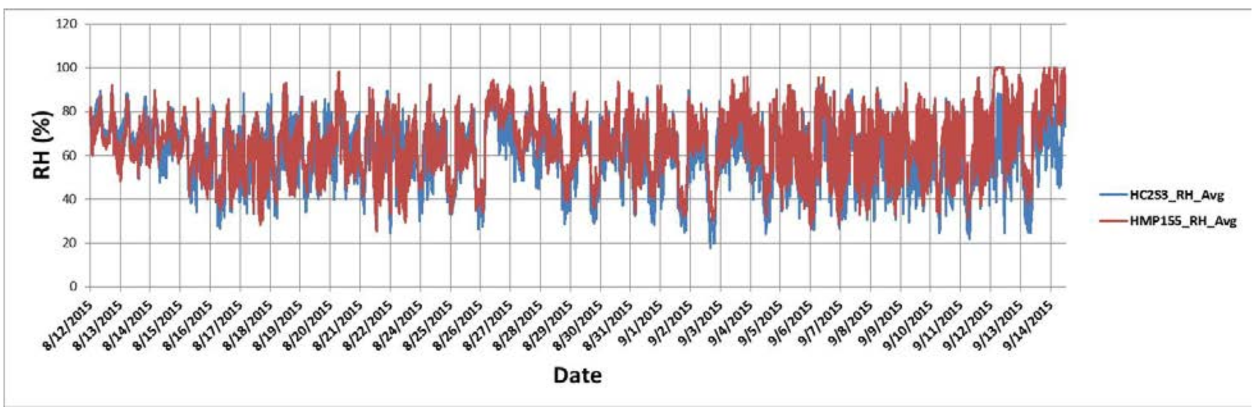

Figure 5. Relative humidity in percent throughout the study for HMP 155 and HC2S3 sensors.

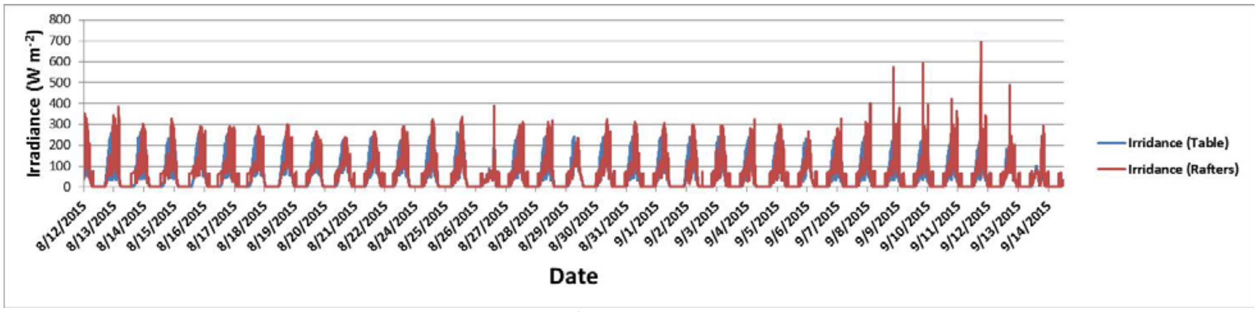

Figure 6. Shortwave radiation in W m^{-2} throughout the study for two pyranometers placed in different location of the greenhouse.

Leaf wetness depths for each treatment over the entire study are shown in Figure 7. The usefulness of having continuous data collection is shown by the data of August 20, 27 and September 12. On August 20 and September 12 there was a single treatment that did not shut off at the end of the day and continued to run at full capacity overnight until returning to the designated treatment level at the beginning of the following day. While the cause of the anomaly is unknown, having a record of its occurrence can be invaluable in determining experimental or production results after the fact. In real time, having an on-line indication of failure to mist such as seen on August 27 permits rapid investigation that may prevent crop damage. In this case, the issue was caused by a hose that had fallen out of the water tanks that supplied the water to the greenhouse allowing the tanks to empty. The issue was immediately corrected and no further problems were seen.

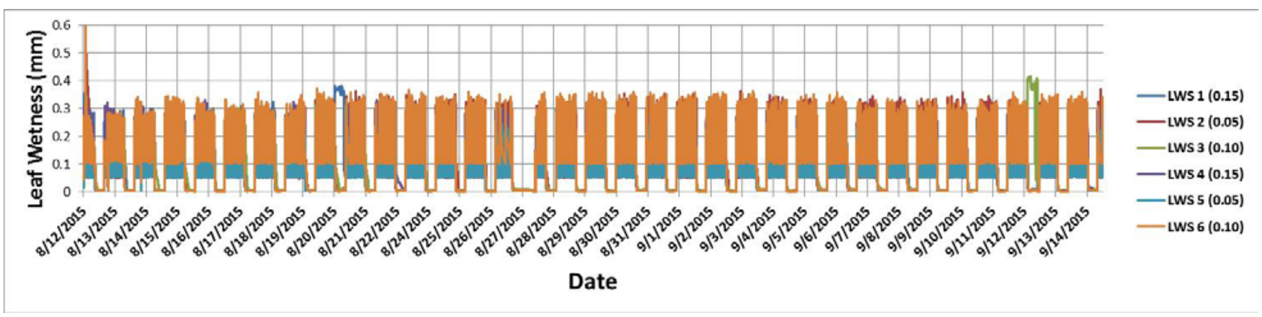

Figure 7. Leaf wetness depths in mm for each treatment throughout the duration of the study.

To show the flexibility of the system to variable environmental conditions, two contrasting days were selected according the difference in irradiance. August 21 (Figure 8) was a day of low irradiance and September 12 (Figure 9) was a day of high irradiance. Note how the LWS 6 (0.10mm) treatment has very few misting events during the first half of the day on August 21 before misting events become more frequent in response to increased irradiance later in the day. In contrast, September 12 has a very short period in the morning when misting events are few before increasing in response to increased irradiance. These trends are similar to those produced by Crook (2012). These graphs also indicate distinct separation between the treatments each day, similar to the output on the monitoring screen.

Misting events per day were also recorded (Figure 10). There was good separation of the 0.15 mm treatments from the two lower treatments, however not much separation between the 0.10 and 0.05 mm treatments. This graph also indicates that there were fairly constant misting events each day with a gradual increase towards the end of the study. The LWS 4 (0.15 mm) produced the most variability in misting events on a daily basis and was also much higher than the other 0.15 mm treatment. This was apparent in the beginning of the study; however, it is uncertain why there was so much variation in misting frequency between the two replicates of the 0.15 mm treatment. Possible explanations include variable runoff from the sensor or some kind of failure within the sensor itself.

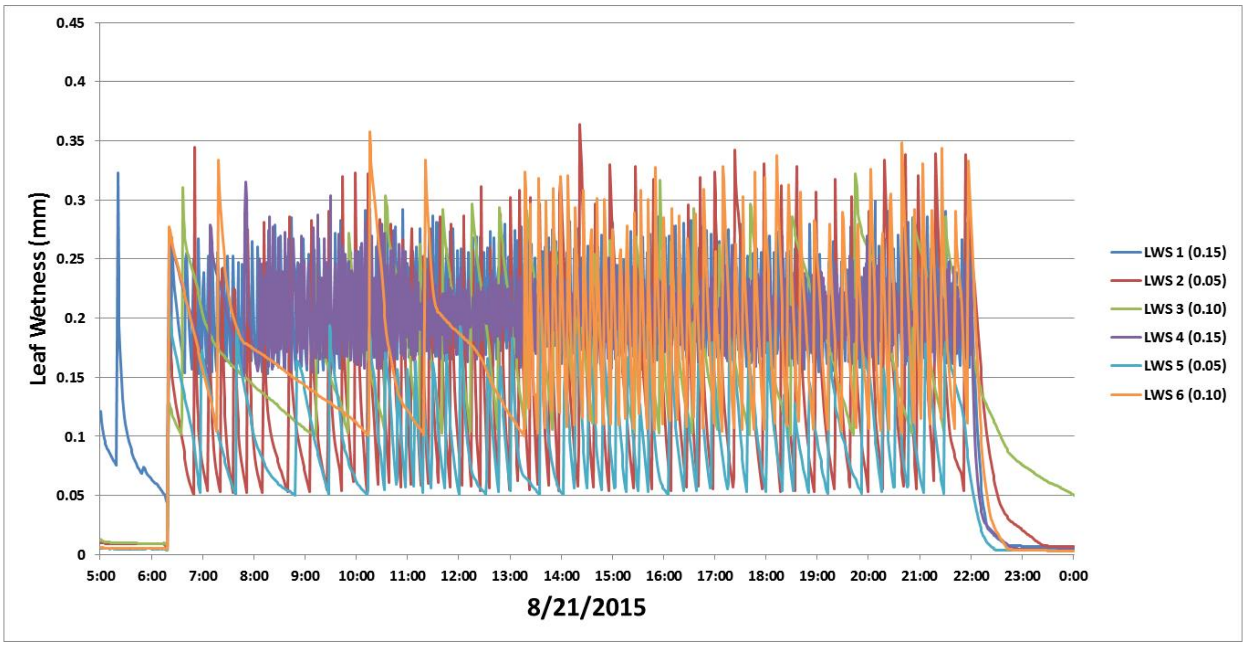

Figure 8. Leaf wetness responses for each treatment on a low irradiance day August 21.

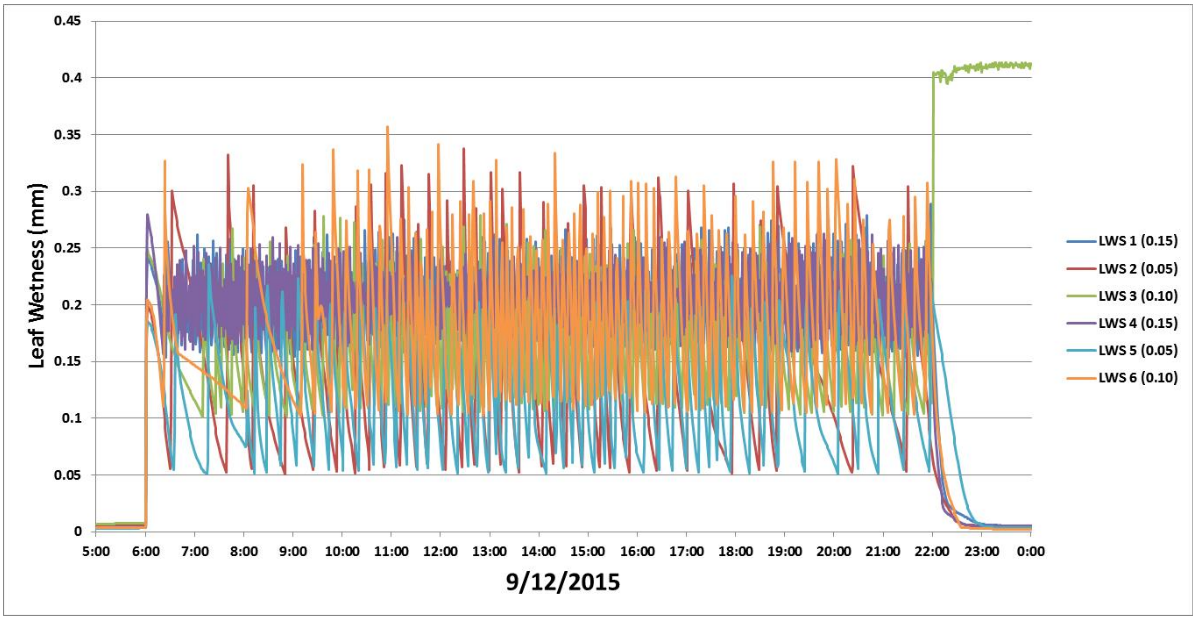

Figure 9. Leaf wetness responses for each treatment on a low irradiance day September 12.

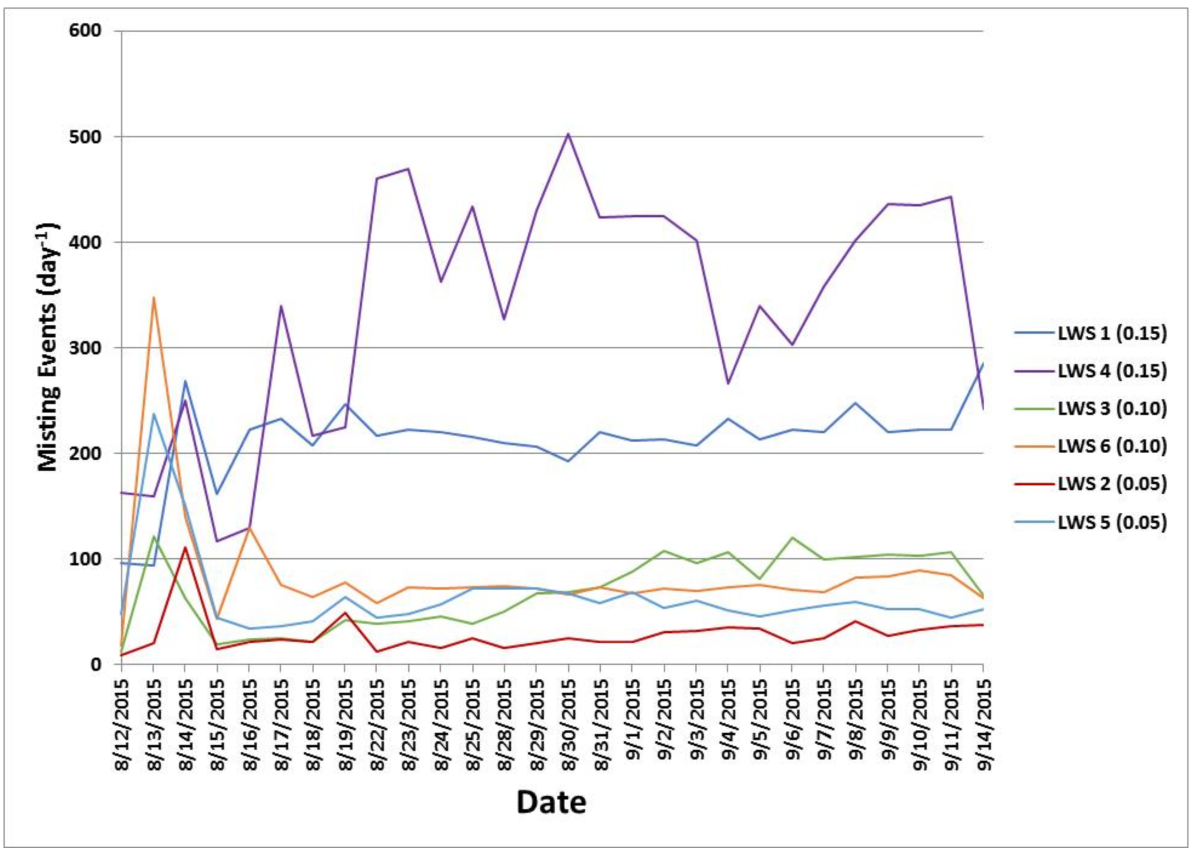

Figure 10. Misting events per day for each treatment over the course of the study.

The impact of the mist system on rooting of cuttings is shown in Table 1. The only statistically significant difference occurred for the longest root produced. Interestingly, the single longest root on the cuttings in the 0.15 treatment was significantly longer than those in the 0.10 treatment but not the 0.05 treatment. The lack of a linear trend in root length due to misting treatment suggests it was not a significant effect. Overall, these results indicate that all treatment levels provided sufficient misting for root formation. In future research, the treatment levels should be reduced to 0.025, 0.05, and 0.10 to see if there is a minimum threshold of misting required for rooting of *Shepherdia* cuttings.

Misting events per day was also analyzed to determine if there was clean separation between the treatments. The results indicate that the 0.15 treatment was significantly different from the lower two treatments, however the 0.10 and 0.05 where not statistically different from one another. This lack of separation could be explained by the variability in the 0.10 treatment on a daily basis.

Table 1. Measurements of *Shepherdia sp.* cuttings made at harvest and number of misting events per day.

Treatment	Percent rooted	Number of roots	Longest root (mm)	Misting Event (day^{-1})
0.05	83% (a)†	6.1 (a)	38.4 (ab)	46.5 (b)
0.10	85% (a)	6.9 (a)	31.6 (b)	76.6 (b)
0.15	93% (a)	7.4 (a)	44.9 (a)	275.6 (a)

† Vertical means (lower case letters) followed by the same letter within a column are not significantly different (p=0.05).

This misting system could be incorporated by growers to achieve optimal environmental conditions for effective plant propagation by basing mist treatments on surface moisture levels, thus integrating the entire environment into one sensor.

These results indicate that while there was variation in the LWS, it does provide proof of concept for controlling misting frequency and confirms results by Crook (2012). This system also allows for continuous data collection not historically done with traditional controllers. When such data is made available on-line it provides a tremendous tool for propagators in real-time monitoring of intermittent mist systems. Further improvements in the technology such as the ability to remotely adjust system parameters via the Internet are also possible.

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Appendix

Datalogger program for new sensors and automation of misting system

```
'CR1000 Series Datalogger Program
'automated mister system
'date: May 7, 2015
'program author: Chase Snowden

Public PTemp, batt_volt, High_Fan, Low_Fan, Low_Fan_On, High_Fan_On, C1,
LWS_Depth_1_Mist_Event,
Public LWS_Depth_2_Mist_Event, LWS_Depth_3_Mist_Event,
LWS_Depth_4_Mist_Event, LWS_Depth_5_Mist_Event, LWS_Depth_6_Mist_Event

Const DepthSet1 = 0.025
Const DepthSet2 = 0.05
Const DepthSet3 = 0.075
Const DepthSet4 = 0.10
Const DepthSet5 = 0.125
Const DepthSet6 = 0.15

'Time Parameters
Public RTime (9)
Alias RTime (1) = Year
Alias RTime (2) = Month
Alias RTime (3) = DayMonth
Alias RTime (4) = Hour
Alias RTime (5) = Minute
```

```
Alias RTime (6) = Second
Alias RTime (7) = Microsecond
Alias RTime (8) = DayWeek
Alias RTime (9) = DayYear

'Incoming shortwave radiation
Public pyrano_1, pyrano_2

'Relstive Humidity and Temperature
Public HMP155_RH, HC2S3_RH, HMP155_Temp, HC2S3_Temp,
SatVapPressHMP155, VapPressHMP155, SatVapPressHC2S3, VapPressHC2S3,
VPD_HMP155, VPD_HC2S3,
Public Phyto_RH, Phyto_Temp, SatVapPressPhyto, VapPressPhyto, VPD_Phyto


'Leaf Wetness Sensors
Public LWS (6), Bench_2_avg, Bench_3_avg, LWS_Depth (6)
Alias LWS (1) = LWS_1
Alias LWS (2) = LWS_2
Alias LWS (3) = LWS_3
Alias LWS (4) = LWS_4
Alias LWS (5) = LWS_5
Alias LWS (6) = LWS_6
Alias LWS_Depth (1) = LWS_Depth_1
Alias LWS_Depth (2) = LWS_Depth_2
Alias LWS_Depth (3) = LWS_Depth_3
Alias LWS_Depth (4) = LWS_Depth_4
Alias LWS_Depth (5) = LWS_Depth_5
Alias LWS_Depth (6) = LWS_Depth_6

'Define Data Tables
DataTable (Mister_System_Min,1,-1)
	DataInterval (0,1,Min,10)
	Minimum (1,batt_volt,IEEE4,0,False)
	Average (1,PTemp,IEEE4,False)
	Average (1,pyrano_1,IEEE4,False)
	Average (1,pyrano_2,IEEE4,False)
	Average (1,HC2S3_RH,IEEE4,False)
	Average (1,HMP155_RH,IEEE4,False)
	Average (1,HC2S3_Temp,IEEE4,False)
	Average (1,HMP155_Temp,IEEE4,False)
	Sample (1,High_Fan,IEEE4)
	Sample (1,Low_Fan,IEEE4)
	Sample (1,High_Fan_On,IEEE4)
	Sample (1,Low_Fan_On,IEEE4)
	Average (1,VPD_HMP155,IEEE4,False)
```

```
        Average (1,VPD_HC2S3,IEEE4,False)
                Average (1,LWS_Depth_1,IEEE4,False)
                Average (1,LWS_Depth_2,IEEE4,False)
                Average (1,LWS_Depth_3,IEEE4,False)
                Average (1,LWS_Depth_4,IEEE4,False)
                Average (1,LWS_Depth_5,IEEE4,False)
                Average (1,LWS_Depth_6,IEEE4,False)

EndTable

DataTable (Misting_Event,1,-1)
        DataInterval (0,5,Sec,10)
Sample (1,LWS_Depth_1_Mist_Event,IEEE4)
Sample (1,LWS_Depth_2_Mist_Event,IEEE4)
Sample (1,LWS_Depth_3_Mist_Event,IEEE4)
Sample (1,LWS_Depth_4_Mist_Event,IEEE4)
Sample (1,LWS_Depth_5_Mist_Event,IEEE4)
Sample (1,LWS_Depth_6_Mist_Event,IEEE4)
EndTable

DataTable (Mister_System_Hr,1,-1)
        DataInterval (0,1,Hr,10)
        Minimum (1,batt_volt,IEEE4,0,False)
        Average (1,PTemp,IEEE4,False)
        Average (1,pyrano_1,IEEE4,False)
        Average (1,pyrano_2,IEEE4,False)
        Average (1,HC2S3_RH,IEEE4,False)
        Average (1,HMP155_RH,IEEE4,False)
        Average (1,HC2S3_Temp,IEEE4,False)
        Average (1,HMP155_Temp,IEEE4,False)
        Sample (1,High_Fan,IEEE4)
        Sample (1,Low_Fan,IEEE4)
        Sample (1,High_Fan_On,IEEE4)
        Sample (1,Low_Fan_On,IEEE4)
        Average (1,VPD_HMP155,IEEE4,False)
        Average (1,VPD_HC2S3,IEEE4,False)
                Average (1,LWS_Depth_1,IEEE4,False)
                Average (1,LWS_Depth_2,IEEE4,False)
                Average (1,LWS_Depth_3,IEEE4,False)
                Average (1,LWS_Depth_4,IEEE4,False)
                Average (1,LWS_Depth_5,IEEE4,False)
                Average (1,LWS_Depth_6,IEEE4,False)
EndTable

'Main Program
BeginProg
```

```
        Scan (5,Sec,0,0)
                PanelTemp (PTemp,_60Hz)
                Battery (batt_volt)

'Incoming shortwave radiation
  VoltSe (pyrano_1,1,mV250,1,1,0,_60Hz,5,0)
        VoltSe (pyrano_2,1,mV250,2,1,0,_60Hz,5,0)


'Relstive Humidity and Temperature
  'HMP155
    VoltSe (HMP155_Temp,1,mV2500,3,1,0,_60Hz,0.14,-80)
    VoltSe (HMP155_RH,1,mV2500,4,1,0,_60Hz,.1,0)
    If HMP155_RH>100 AND HMP155_RH<103 Then HMP155_RH=100
    SatVP (SatVapPressHMP155,HMP155_Temp)
    VaporPressure (VapPressHMP155,HMP155_Temp,HMP155_RH)
    VPD_HMP155 = SatVapPressHMP155 - VapPressHMP155

  'HC2S3
    VoltSe (HC2S3_Temp,1,mV2500,13,1,0,_60Hz,0.1,-40)
    VoltSe (HC2S3_RH,1,mV2500,14,1,0,_60Hz,0.1,0)
    If HC2S3_RH>100 AND HC2S3_RH<103 Then HC2S3_RH=100
    SatVP (SatVapPressHC2S3,HC2S3_Temp)
    VaporPressure (VapPressHC2S3,HC2S3_Temp,HC2S3_RH)
    VPD_HC2S3 = SatVapPressHC2S3 - VapPressHC2S3

 'Leaf Wetness Sensors
  BrHalf (LWS_1,1,mV2500,7,Vx1,2,2500,False,0,_60Hz,2500,0)
  BrHalf (LWS_2,1,mV2500,8,Vx1,2,2500,False,0,_60Hz,2500,0)
  BrHalf (LWS_3,1,mV2500,9,Vx2,2,2500,False,0,_60Hz,2500,0)
  BrHalf (LWS_4,1,mV2500,10,Vx2,2,2500,False,0,_60Hz,2500,0)
  BrHalf (LWS_5,1,mV2500,11,Vx3,2,2500,False,0,_60Hz,2500,0)
  BrHalf (LWS_6,1,mV2500,12,Vx3,2,2500,False,0,_60Hz,2500,0)
  Bench_2_avg = ((LWS_1 + LWS_2 + LWS_3) / 3)
  Bench_3_avg = ((LWS_4 + LWS_5 + LWS_6) / 3)
  LWS_Depth_1 = (LWS_1*0.08155-20.895)/100
  LWS_Depth_2 = (LWS_2*0.07955-20.895)/100
  LWS_Depth_3 = (LWS_3*0.08100-20.895)/100
  LWS_Depth_4 = (LWS_4*0.08100-20.895)/100
  LWS_Depth_5 = (LWS_5*0.07960-20.895)/100
  LWS_Depth_6 = (LWS_6*0.08100-20.895)/100

'Exhaust Fans on or off
   VoltDiff (High_Fan,1,mV2500,3,False,0,_60Hz,1.0,0)
   VoltDiff (Low_Fan,1,mV2500,8,False,0,_60Hz,1.0,0)
   If High_Fan>2100 Then High_Fan_On = 1 Else High_Fan_On = 0
```

```
        If Low_Fan>2100 Then Low_Fan_On = 1 Else Low_Fan_On = 0

'Daily Cycling of Misters
RealTime (RTime())
  If Hour >= 6 AND Hour <= 21 Then

If LWS_Depth_1 <= DepthSet6 Then PortSet 1,1
 If LWS_Depth_1 > DepthSet6 Then PortSet 1,0
 LWS_Depth_1_Mist_Event = CheckPort (1 )


If LWS_Depth_2 <= DepthSet2 Then PortSet 2,1
 If LWS_Depth_2 > DepthSet2 Then PortSet 2,0
 LWS_Depth_2_Mist_Event = CheckPort (2 )

If LWS_Depth_3 <= DepthSet4 Then PortSet 3,1
 If LWS_Depth_3 > DepthSet4 Then PortSet 3,0
 LWS_Depth_3_Mist_Event = CheckPort (3 )

If LWS_Depth_4 <= DepthSet6 Then PortSet 4,1
 If LWS_Depth_4 > DepthSet6 Then PortSet 4,0
 LWS_Depth_4_Mist_Event = CheckPort (4 )

If LWS_Depth_5 <= DepthSet2 Then PortSet 5,1
 If LWS_Depth_5 > DepthSet2 Then PortSet 5,0
 LWS_Depth_5_Mist_Event = CheckPort (5 )

If LWS_Depth_6 <= DepthSet4 Then PortSet 6,1
 If LWS_Depth_6 > DepthSet4 Then PortSet 6,0
 LWS_Depth_6_Mist_Event = CheckPort (6 )

EndIf

CallTable Mister_System_Min
CallTable Mister_System_Hr
CallTable Misting_Event
        NextScan
EndProg
```

Diversity Studies and Interspecific Hybridization in *Penstemon* in 2015

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Brigham Young University; Plant and Wildlife Sciences, Provo, UT 84602

This report briefly summarizes the research we have conducted on *Penstemon* since our 2014 report. Beginning summer 2013 we initiated a study to try to understand the genetic diversity of *P. scariosus*. Early spring 2014 we received word that we were to be awarded a small grant from Bureau of Land Management (BLM) for the Uinta Basin of Colorado and Utah to continue to address the question of the genetic diversity *P. scariosus*. Since that time we have been collecting plant tissue samples, performing DNA laboratory analysis, and are now analyzing the resulting data from those laboratory tests. All of our preliminary data clearly indicate that the presently delineated *P. scariosus* var. *albifluvis* and *P. fremontii* var. *glabrescens* are very distinct from *P. scariosus* var. *scariosus*, *P. scariosus* var. *garrettii*, *P. scariosus* var. *cyanomontanus*, and *P. fremontii* var. *fremontii*. Furthermore, *P. scariosus* var. *albifluvis* (Fig. 1) and *P. fremontii* var. *glabrescens* (Fig. 2 and 3) are so unique that they should be considered independent species. The reason for including *P. fremontii* var. *glabrescens* in this study was that it has been regularly confused as being a *P. scariosus* by a number of well-qualified botanists. This was reflected by the specimens of this taxon found in the Stanley L. Welch Herbarium at the Monte L. Bean Life Science Museum at Brigham Young University. We are presently working on the final iterations of our data and preparing a manuscript which will present these findings. We will recommend that *P. scariosus* var. *albifluvis* be returned to its former species status when it was initially classified as *P. albifluvis* (England, 1982). We are also preparing a second manuscript which presents data that clearly indicate that *P. fremontii* var. *glabrescens* be elevated to a species in its own right. We will be proposing the name for this taxon to be *P. luculentus*. There are no evidence in our data that remaining *P. scariosus* should be subdivided to other species. The data we are working on now will help us determine if the designations of the varieties *scariosus*, *garrettii*, and *cyanomontanus* can also be identified with the molecular techniques we used.

Figure 1. *Penstemon albifluvis*. Prior to our research this species was recognized as *P. scariosus* var. *albifluvis* because Holmgren (1984) "lumped" it with the *P. scarious* complex.

Figure 2. *Penstemon luculentus*. Prior to our research this species was recognized as *P. fremontii* var. *glabrescens* following Dorn and Lichvar (1990) who originally described this taxon.

Figure 3. Hill side of *Penstemon luculentus* in bloom in the upper reaches of Piceance Canyon in Colorado.

The second element of our *Penstemon* diversity studies was the receipt of multi-year funding during the summer of 2015 to study the genetic diversity of *Penstemon cyaneus*. This species is mostly found across the southern half of Idaho (Snake River Valley and drainages to the north) and into the regions of Montana and Wyoming surrounding the Yellowstone and Grand Teton National Parks. The funding covers sample collections across the region, common garden studies, tissue sample molecular analysis, and a graduate student to take charge of these studies. With the assistance of Stephen Love, University of Idaho Extension Service out of Aberdeen, ID, and a comprehensive study of multiple herbarium records we collected pressed plant samples, tissue samples for molecular analysis, and seed from ~50 sample locations. This effort required multiple trips into the region resulting approximately12,000 road miles during late spring and summer of 2015. It is our objective to try to gain an improved understand the genetic diversity of this species and how it relates to its close relatives. Using a borrowed name from Stephen Love we have come to affectionately call this project “The Big Blue Penstemon Project.” The name is derived from morphological similarities that must be taken into consideration among *P. cyaneus* and similar blue flowered species with large blooms that intermix within this geographical region.

Finally, we have succeeded in growing *Penstemon* interspecific hybrid plants from crosses made during the 2014 growing season (Table 1). Using 19 unique taxa from 4 subgenera (Table 2) we have obtained seed from 44 different interspecific cross combinations (Table 3; Fig. 4A&B). These 4 subgenera make up the majority of the 6 total subgenera generally recognized with the genus *Penstemon* (Wolfe et al., 2006).

Figure 4 A&B. Plants of the example female parent plant of *P. eatonii* (A) and *P. pseudospectabilis* (B) with tags of crossing identification information.

Table 1. Interspecific *Penstemon* hybrids from 2014 crossed with observations on plant phenotype.

Cross	# of plants	Notes
P. eatonii × *P. pseudospectabilis*	1	Bloomed in the fall and plant and flower looked very much like *P. eatonii*.
P. eatonii *P. palmeri*	7	Plants all have some leaf serration and plants from one *P. palmeri* parentage have a very glaucous-like leaf where plants from a different *P. palmeri* parent is closer to the dark green narrow leaf found in *P. eatonii*. Most of the crosses are with the same *P. eatonii* parent.
P. palmeri × *P. laevis*	6	One plant bloomed summer 2015 and the blossom was essentially *P. palmeri* type[1]. Crosses were made with this plant (see Table 2).
P. eatonii × *P. laevis*	3	Large, almost ovate, leaves were noted in these crosses.

[1]Having interspecific hybrid F_1 *Penstemon* take on the phenotype of the female parent plant is a phenomenon identified by breeders working within this genus. In several recorded instances, the progeny from these F_1's show the expected segregation from the cross (Viehmeyer, 1954; Viehmeyer, 1965; Viehmeyer, 1973a; Viehmeyer, 1973b).

Table 2. Penstemon species producing pods in 2015 when used as a male, female or both. Photos of each of the following taxa are found in Figures 1, 2, 3, 4A&B, and 5A, B, C, D, E, F, G, H, I, J, K, L, M, N, and O.

Species (Subgenus, Section)	Species (Subgenus, Section)
1-*P. albifluvis*[1] (*Habroanthus, Glabri*)	11-*P. palmeri* (*Penstemon, Peltanthera*)
2-*P. barbatus* (*Habroanthus, Elmigera*)	12-*P. petiolatus* (*Penstemon, Peltanthera*)
3-*P. comarrhenus* (*Habroanthus, Glabri*)	13-*P. pseudospectabilis* (*Penstemon, Peltanthera*)
4-*P. cyananthus* (*Habroanthus, Glabri*)	14-*P. personatus* (*Cryptostemon*)
5-*P. eatonii* (*Habroanthus, Elmigera*)	15-*P. rostriflorus* (*Saccanthera, Bridgesiani*)
6-*P. fremontii* (*Habroanthus, Glabri*)	16-*P. sepalulus* (*Saccanthera, Saccanthera*)
7-*P. gibbensii* (*Habroanthus, Glabri*)	17-*P. scariosus* var. *cyanomontanus* (*Habroanthus, Glabri*)
8-*P. laevis* (*Habroanthus, Glabri*)	18-*P. scariosus* var. *garrettii* (*Habroanthus, Glabri*)
9-*P. luculentus*[2] (*Habroanthus, Glabri*)	19-*P. strictus* (*Habroanthus, Glabri*)
10-*P. pachyphyllus* (*Penstemon, Coerulei*)	

[1]Since 1984 this taxon has been classified as *P. scariosus* var. *albifluvis* (Holmgren, 1984); however, the results of our recent research has clearly supported the idea this is a unique species, as it was originally classified (England, 1982). A peer reviewed publication proposing this change has been submitted.
[2]This taxon was originally classified as *P. fremontii* var. *glabrescens* (Dorn and Lichvar, 1990); however, the results of our recent research has clearly suggest that this is a

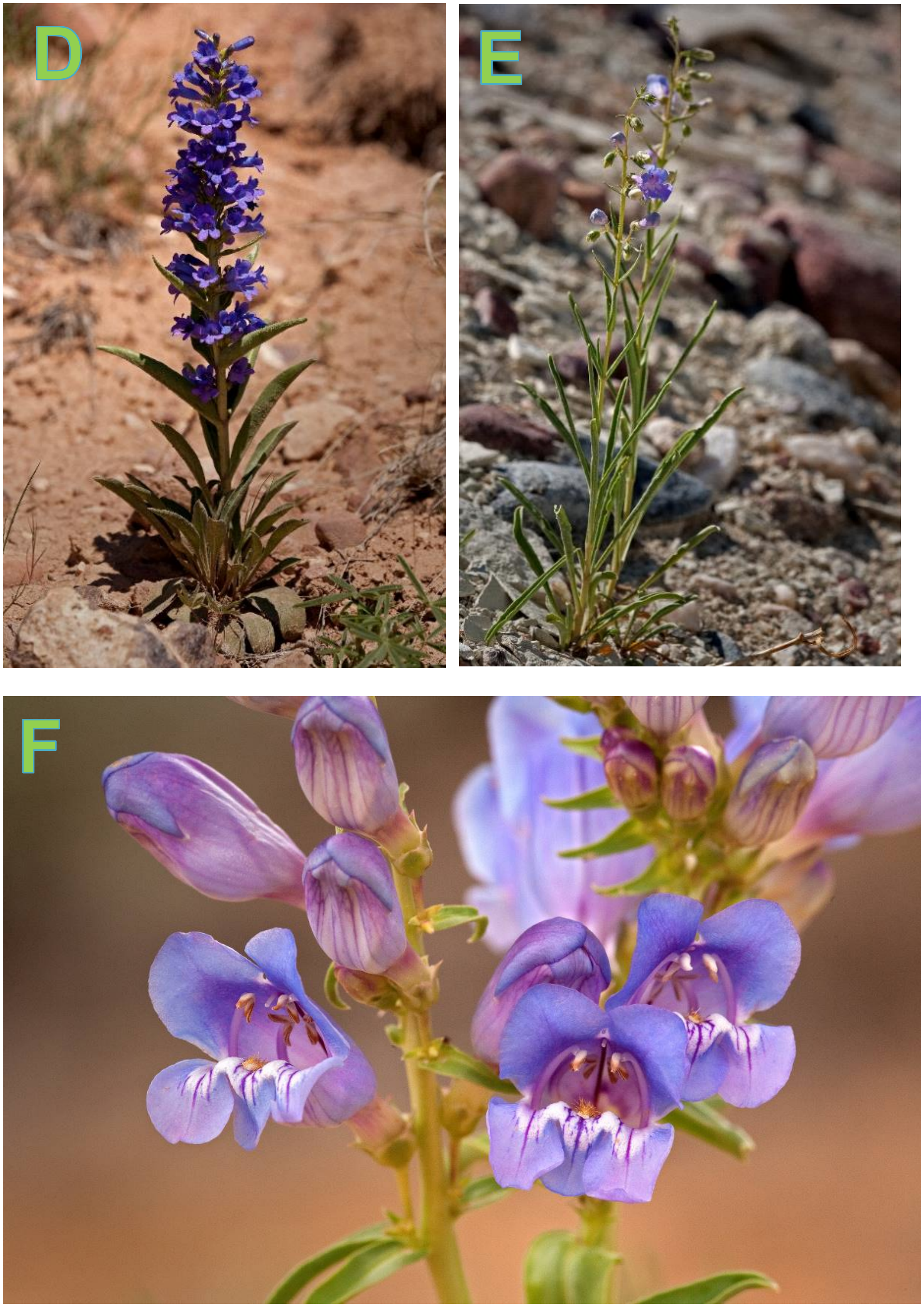
distinctly unique taxon. As a result, we are in the process formalizing this proposed change in a peer reviewed publication.

Table 3. Interspecific hybrid Penstemon seed collected from the 2015 crossing season.

Female × Male	Female × Male
1-*P. barbatus* × *P. comarrhenus*	23-*P. laevis* × *P. palmeri*
2-*P. barbatus* × *P. eatonii*	24-*P. laevis* × *P. pseudospectabilis*
3-*P. barbatus* × *P. laevis*	25-*P. palmeri* × *P. barbatus*
4-*P. barbatus* × *P. palmeri*	26-*P. palmeri* × *P. eatonii*
5-*P. barbatus* × *P. petiolatus*	27-*P. palmeri* × *P. gibbensii*
6-*P. barbatus* × *P. pseudospectabilis*	28-*P. palmeri* × *P. laevis*
7-*P. barbatus* × (*P. palmeri* × *P. laevis*)	29-*P. palmeri* × *P. luculentus*[2]
8-*P. barbatus* × *P. personatus*	30-*P. palmeri* × *P. pachyphyllus*
9-*P. barbatus* × *P. strictus*	31-*P. palmeri* × *P. petiolatus*
10-*P. cyananthus* × *P. pseudospectabilis*	32-*P. palmeri* × *P. pseudospectabilis*
11-*P. eatonii* × *P. albifluvis*[1]	33-*P. palmeri* × *P. scariosus* var. *cyanomontanus*
12-*P. eatonii* × *P. barbatus*	34-*P. palmeri* × *P. strictus*
13-*P. eatonii* × *P. comarrhenus*	35-*P. palmeri* × (*P. eatonii* × *P. pseudospectabilis*)
14-*P. eatonii* × *P. fremontii*	36-*P. pseudospectabilis* × *P. comarrhenus*
15-*P. eatonii* × *P. laevis*	37-*P. pseudospectabilis* × *P. eatonii*
16-*P. eatonii* × *P. palmeri*	38-*P. pseudospectabilis* × *P. palmeri*
17-*P. eatonii* × *P. scariosus* var. *garrettii*	39-*P. albifluvis* × *P. pachyphyllus*
18-*P. eatonii* × *P. pseudospectabilis*	40-*P. albifluvis* × *P. scariosus* var. *cyanomontanus*
19-*P. fremontii* × *P. albifluvis*	41-*P. scariosus* var. *cyanomontanus* × *P. fremontii*
20-*P. laevis* × *P. barbatus*	42-*P. scariosus* var. *cyanomontanus* × *P. cleburnei*
21-*P. laevis* × *P. comarrhenus*	43-*P. scariosus* var. *garrettii* × *P. pseudospectabilis*
22-*P. laevis* × *P. eatonii*	44-*P. rostriflorus* × *P. sepalulus*

[1]Since 1984 this taxon has been classified as *P. scariosus* var. *albifluvis* (Holmgren, 1984); however, the results of our recent research has clearly supported the idea this is a unique species, as it was originally classified (England, 1982). A peer reviewed publication proposing this change has been submitted.
[2]This taxon was originally classified as *P. fremontii* var. *glabrescens* (Dorn and Lichvar, 1990); however, the results of our recent research has clearly suggest that this is a distinctly unique taxon. As a result, we are in the process formalizing this proposed change in a peer reviewed publication.

Figure 5. **A=*P. barbatus* var. *trichander*, B=*P. comarrhenus*, C=*P. cyananthus*, D=*P. fremontii*, E=*P. gibbensii*, F=*P. laevis*, G=*P. pachyphyllus*, H=*P. palmeri*, I=*P. petiolatus*, J=*P. personatus*, K=*P. rostiflorus*, L=*P. sepalulus*, M=*P. scariosus* var. *cyanomontanus*, N=*P. scariosus* var. *garrettii*, and O=*P. strictus*.**


D
E
F


G


H


I


J


K


L


M


N


O

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