



United States Department of Agriculture

August 2022

## **16-Year Case Study of Bluebunch Wheatgrass and Snake River Wheatgrass Plant Materials in Idaho's Snake River Plain**

Derek Tilley, Mary Wolf



Derek Tilley, Aberdeen PMC Manager; Mary Wolf, Aberdeen PMC Agronomist. 1691 A South 2700 West, Aberdeen, Idaho 83210; [derek.tilley@usda.gov](mailto:derek.tilley@usda.gov)

## ABSTRACT

While plant materials releases have typically undergone some level of testing, long-term comparisons and evaluations are relatively few. Understanding long-term environmental adaptation of species and plant releases is critical for persistent site restoration and rehabilitation. Idaho NRCS established a multi-species display nursery in the semiarid Snake River Plain at Orchard, ID in 2004. The display nursery included eight entries of bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Á. Löve [Poaceae]) and five Snake River wheatgrass (*Elymus wawawaiensis* J. Carlson & Barkworth [Poaceae]) entries which were evaluated yearly for plant density from 2005 through 2008, and again in 2021. In this non-replicated case study, we found several bluebunch and Snake River wheatgrass accessions and releases adapted to local site conditions while not being of local origin. Our observations further suggest that Anatone bluebunch wheatgrass may be better adapted to lower precipitation areas than Golder. We did not see evidence that Snake River wheatgrass was more drought tolerant than bluebunch releases at the Orchard study site, but rather we saw significant variation between releases or accessions.

## Key Words

Long-term persistence, adaptation, range, grass, seed transfer

## Nomenclature

USDA NRCS (2022)

## INTRODUCTION

Promising plant materials can undergo a wide range of evaluation during development depending on the class of release targeted. Historically, cultivar releases have been through replicated testing at multiple sites over two or more generations spanning on average 7 to 11 years (USDA NRCS 2010), while pre-varietal germplasms (PVG) are evaluated much less (DePue and Englert 2015). For example, Selected-class germplasms may only be evaluated for 1 to 2 years of a single generation prior to release (Tilley 2015) or for 3 to 6 years in some cases (LeFebvre and others 2017), while Source Identified releases are made from a naturally growing population occupying a known or defined geographic area, with minimal or no selection or testing of the parent population (USDA NRCS 2004; USDA NRCS 2010).

Despite the time invested in the development of many plant materials releases, observations lasting beyond a handful years are few. This may lead to an incomplete understanding in the scope of adaptation of plant materials being used across a broad spatial range. Conditions in the semiarid sagebrush steppe ecosystem in the Snake River Plain of western North America for example are highly variable. Temperatures can range from -40 °C (-40 °F) in winter to 40 °C (104 °F) in summer (Caldwell 1985), while normal precipitation ranges from 125 to >300 mm (5 to 12 inches) (McNab 1996). The majority of precipitation falls as snow in winter and spring, outside of the growing season (Smith and others 2012), and plant growth depends largely on soil water accumulated over the previous winter (Comstock and Ehleringer 1992). Swings in temperatures, precipitation, as well as fungal or insect outbreaks, may not be captured in short-term studies and their effect on test materials can remain undetected prior to release and not become apparent for many years.

There is growing understanding of which species have more strict or broad ecological adaptation; however, it is accepted by many that local ecotypes should be preferred for restoration projects

(Aubry and others 2005). There is concern that the use of non-local ecotypes could result in undesired genetic swamping, outbreeding depression (Mckay and others 2013), or restoration failure due to not being adapted to local site conditions (Darris 2001; Mckay and others 2013). However, this may not always be the case (Jensen and others 2020). Manipulated-track releases bred for improved seedling vigor, or natural-track releases from harsher environments, may be better adapted to the current conditions of a location as compared to the local ecotype that evolved under different historical conditions. Likewise, genotypic blends and polycrosses of high genetic diversity have been suggested as a form of insurance for broad adaptation (Jones and others 2002). While genecological studies and molecular analyses can elucidate genotypic and phenotypic differences between populations, they may not be able to adequately describe long term fitness in a changing environment. To this end, long term observations of plant material performance remain incredibly valuable.

Bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Å.

Löve [Poaceae]) (Figure 1) is the dominant bunchgrass throughout much of the Intermountain West's semiarid sagebrush steppe (St. Clair and others 2013). It is highly palatable and is considered desired forage for a variety of livestock and ungulates (Ogle and others 2010), making it one of the most important grasses to rangeland management (USDA FS 1937). Snake River wheatgrass (*Elymus wawawaiensis* J. Carlson & Barkworth [Poaceae]) is a native of the canyons of the Snake River and its tributaries in Washington, eastern Oregon, and western to northern Idaho. It is similar in appearance to bluebunch wheatgrass, but differs morphologically in having narrower, acuminate (pointed) to aciculate (needle-like) glumes, a more imbricate (overlapping) spike, and glabrate basal leaf sheaths. Snake River wheatgrass was for years misidentified as bluebunch wheatgrass (Barkworth and Carlson 1997), and though it occupies a similar niche, it has been shown to be generally more drought tolerant and have better establishment in low precipitation areas (Monsen and others 2003). For this reason, it is often recommended as a substitute for bluebunch in drier sites (Ogle and others 2002), even though the site may be outside of the natural range of Snake River wheatgrass. However, this use of Snake River wheatgrass outside of its native range may be a concern for those wishing to preserve species composition and distribution.

These two grasses are the most broadly seeded native species in the Great Basin in terms of acres covered and volume of seed planted (Gunnell 2021). For example, Utah Division of Wildlife Resources shipped a yearly average of approximately 18,000 kg (40,000 lb) of bluebunch wheatgrass and 15,000 kg (33,000 lb) of Snake River wheatgrass to restoration sites between 2006 and 2019. Over those years, bluebunch and Snake River wheatgrasses combined amounted to 9% of the total shipped seed and 18% of native species (Gunnell 2021).



Figure 1. Bluebunch wheatgrass is a widely distributed and commonly seeded native perennial bunchgrass in Intermountain rangelands. Photo by Derek Tilley, NRCS.

In efforts to assure seed source to site matching, seed transfer zones are being developed using various analyses. Genecological studies examining variation of phenotypic traits in relation to environmental conditions have been used to develop seed transfer guidelines of many restoration species (Johnson and others 2013; St. Clair and others 2013; Kramer and others 2015). St. Clair and others (2013) proposed 11 seed zones for bluebunch wheatgrass based on plant size, leaf width and phenology. More recently, Massatti and others (2018) inferred population history from genetic information and proposed four large genetic clusters for western North America within which seed transfer might be appropriate.

Released germplasms of both species are widely used by land management agencies such as USDA Forest Service (FS), USDI Bureau of Land Management (BLM) and private landowners and conservation groups; however, long-term plant survival observations are needed to determine which plant materials can persist beyond the initial establishment years and increase and compete on the changing Intermountain landscape. The Orchard Display Nursery was planted in 2004 in cooperation with the Great Basin Native Plant Selection and Increase Project to allow managers to make side by side comparisons of released and test materials. The nursery has remained, thanks to management by BLM, and now offers a rare opportunity to observe long-term trends of many materials in semiarid sagebrush steppe.

## MATERIALS AND METHODS

The Orchard Test Site is located in the Snake River Plain of Idaho approximately 37 km (22 mi) southeast of Boise at an elevation of 975 m (3,200 ft) (Figure 2). Soils at the site are sandy loams of the Lankbush-Chardoton complex (USDA-NRCS 2021a). Mean annual precipitation for the location is 290 mm (11.6 in), most of which falls as winter snow (PRISM 2021). The plant community is described by NRCS as a Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* [Asteraceae])-bluebunch wheatgrass-Thurber's needlegrass (*Achnatherum thurberianum* [Poaceae]) site (Table 1) (USDA-NRCS 2021b). The site falls clearly within St. Clair and others' (2013) seed transfer zone 3a from which bluebunch wheatgrass plants were shown to be of medium size, have early phenology, and narrow leaf width. The genetic clusters delineated by Massatti and others (2018) however, did not include representatives from the lower Snake River Plain where the Orchard test site is located. The site would appear to fall between the Western Great Basin and the Eastern Great Basin metapopulations (Massatti et al., 2018).

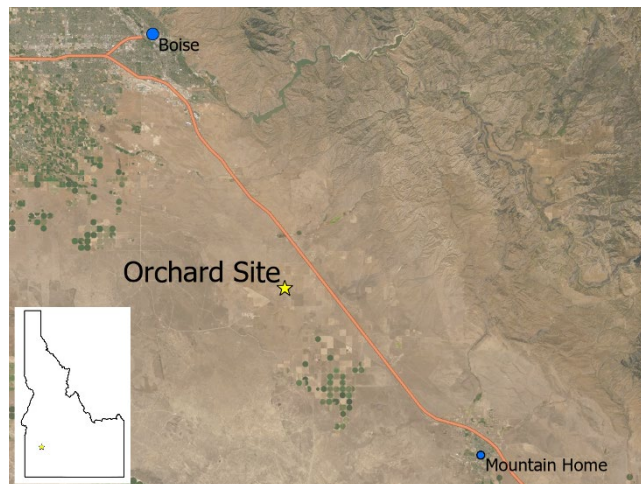


Figure 2. The Orchard test site is located 37 km southeast of Boise in the semiarid Snake River Plain. (Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community).

| Table 1. Site Characteristics (USDA-NRCS 2021a) |                                                                   |
|-------------------------------------------------|-------------------------------------------------------------------|
| Soil type                                       | Lankbush-Chardoton complex                                        |
| Soil texture                                    | Sandy loam                                                        |
| Mean annual precipitation                       | 290 mm (11.6 in) (PRISM 2021)                                     |
| Elevation                                       | 975 m (3,200 ft)                                                  |
| Slope                                           | 0-2%                                                              |
| Plant Community                                 | Wyoming big sagebrush-bluebunch wheatgrass- Thurber's needlegrass |

### Tested Materials

The Orchard display nursery included eight entries of bluebunch wheatgrass and five of Snake River wheatgrass from plant releases and from test materials provided by the USDA ARS Forage and Range Research Lab (ARS) in Logan, Utah (Table 2). Adapted varieties of bluebunch wheatgrass were Anatone Selected Class Germplasm, which is often recommended for use in locations receiving above 250 mm (10 in) mean annual precipitation and 'Goldar' and 'P7' which are recommended in 300+ mm (12 in) precipitation sites (Ogle and others 2014). Anatone and Goldar were both originally collected in Asotin County, WA. P-12 is a predecessor population of the release 'Columbia' by four cycles of selection. P-15 is a predecessor of Columbia by 3 cycles and P-24 is a predecessor of Columbia by two cycles (Jones and Mott 2016). P-12 and P-15 were collected near Lind, WA in a 250 mm (10 in) precipitation area. P-7 is a multi-origin polycross of 23 collections and 2 cultivars to provide high genetic diversity within a single germplasm (Jones and others 2002). Wahluke is a source identified release from BFI Native Seeds (2021) collected from a 150 mm (6 in) precipitation site in Franklin County, WA. Jim Creek is likewise a Source Identified germplasm from BFI Native Seeds (2021).

Table 2. Bluebunch wheatgrass and Snake River wheatgrass plant materials entries included in the 2004 Orchard planting.

| Release Name | Common Name            | Scientific Name                | Release Class           | Release Year       |
|--------------|------------------------|--------------------------------|-------------------------|--------------------|
| 'Goldar'     | Bluebunch wheatgrass   | <i>Pseudoroegneria spicata</i> | Cultivar                | 1989 <sup>a</sup>  |
| Anatone      | Bluebunch wheatgrass   | <i>P. spicata</i>              | Selected Class          | 2004 <sup>b</sup>  |
| P-24         | Bluebunch wheatgrass   | <i>P. spicata</i>              | Test Material           | NA                 |
| Wahluke      | Bluebunch wheatgrass   | <i>P. spicata</i>              | Source Identified (BFI) | 2002 <sup>c</sup>  |
| Jim Creek    | Bluebunch wheatgrass   | <i>P. spicata</i>              | Source Identified (BFI) | 2000 <sup>c</sup>  |
| P-5          | Bluebunch wheatgrass   | <i>P. spicata</i>              | Test Material           | NA                 |
| P-7          | Bluebunch wheatgrass   | <i>P. spicata</i>              | Selected Class          | 2002 <sup>d</sup>  |
| P-12         | Bluebunch wheatgrass   | <i>P. spicata</i>              | Test Material           | NA                 |
| P-15         | Bluebunch wheatgrass   | <i>P. spicata</i>              | Test Material           | NA                 |
| 'Secar'      | Snake River wheatgrass | <i>Elymus wawawaiensis</i>     | Cultivar                | 1980 <sup>ae</sup> |
| E-45         | Snake River wheatgrass | <i>E. wawawaiensis</i>         | Test Material           | NA                 |
| SERDP        | Snake River wheatgrass | <i>E. wawawaiensis</i>         | Test Material           | NA                 |
| E-26         | Snake River wheatgrass | <i>E. wawawaiensis</i>         | Test Material           | NA                 |

<sup>a</sup> Alderson and Sharp 1994; <sup>b</sup> Monsen and others 2003; <sup>c</sup> BFI Native Seeds 2021; <sup>d</sup> Jones and others 2002; <sup>e</sup> DePue and Englert 2015

Snake River Wheatgrass is generally considered to be more drought tolerant than bluebunch wheatgrass in lower precipitation areas (200 to 300 mm) (Ogle and others 2014). The cultivar 'Secar' was originally released as bluebunch wheatgrass before further inspection revealed its true

taxonomy. E-26 was developed by one cycle of selection from the cultivar ‘Discovery’, and E-45 descended from Discovery by two cycles (Jones 2021). SERDP and E-26 are test materials that were never released.

#### *Site Preparation and Implementation*

BLM conducted a prescribed burn over the site in the fall of 2002. The site was later treated in May 2003 and May 2004 with 4.7 L glyphosate and 2.35 L 2,4-D per ha to reduce weed cover and prepare a suitable seedbed for planting. Due to limited breakdown of dead grass clumps that would inhibit proper seed placement with a drill, and to ensure a clean seedbed, the planting site was cultivated with a culti-packer just prior to seeding. The trial was planted as a fall-dormant seeding on 16 November 2004, with a modified Tye Drill with a width of 2.0 m (80 in) configured with 8 spouts at 0.25 m (10 in) spacing. Each plot is 2.0 m (80 in) wide and 18.3 m (60 ft) in length. Seeding depths and rates followed Ogle and others (2011) and NRCS Idaho practice standards which target a seeding depth of 13 to 19 mm (0.5 to 0.75 in) and a seeding rate of 270 to 320 pure live seeds (PLS) per m<sup>2</sup> (25 to 30 PLS/ft<sup>2</sup>) for both species. Pure live seed values were determined by seed laboratory results. All seed was mixed with rice hulls as an inert carrier to improve seed flow following St. John and others (2005). No supplemental irrigation or fertilizer was applied at any time.

During the first evaluation (2005) most plots contained high densities of Russian thistle (*Salsola* sp. [Chenopodiaceae]) and moderate amounts of bur buttercup (*Ranunculus testiculatus* Crantz [Ranunculaceae]). Russian thistle plants were approximately two to three inches tall, and the buttercup plants had already flowered. The plots seeded to grasses were consequently sprayed on 9 June 2005 with 1.2 L 2,4-D and 0.6 L dicamba per ha to control the broadleaf weeds. At the time of the second evaluation (2006), there was a heavy infestation of tumble mustard (*Sisymbrium altissimum* L. [Brassicaceae]); however, no further weed control measures were taken for the duration of the trial.

#### *Analysis*

Because bluebunch wheatgrass and Snake River wheatgrass are often treated as interchangeable by restorationists, we analyzed both species together and not as separate identities. We evaluated plant density by placing 5, 1 m<sup>2</sup> frames in the plot every 2 m (80 in) starting from the northern end of each plot and counting the number of individual plants with at least some rooted material within the frame. Canopy cover was ocularly estimated using the same 5 frames. Plant density data were collected yearly in early to mid-summer from 2005 through 2008 and again in 2021. Canopy cover was evaluated on 2 April 2021. Because the site was planted as a display nursery and not a replicated trial, true blocks and replications were not possible for more rigorous statistical analysis. We treated the 5 frames as pseudo replications to generate means and standard errors as an indicator of variation within the plot. The data presented here should be viewed therefore as a case study and not as a scientific experiment. Conclusions should not be viewed as definitive.

#### *Weather*

Precipitation data for the Orchard Test Site was obtained from PRISM (2021). Average annual precipitation for the 2004-2020 study period was 304 mm (12.0 in), slightly above the long-term (1981-2010) average of 294 mm (11.6 in). Annual and long-term average precipitation are shown in Figure 3. The first three years of the study received near- or above-average precipitation, 276 to 332 mm (11 to 13 in). Five years of the study received less than 250 mm, with 2013 being the driest year at 179 mm (7 in). Precipitation exceeded 380 mm (15 in) in four years of the study. The wettest year

was 2010, with a total of 420 mm (17 in).

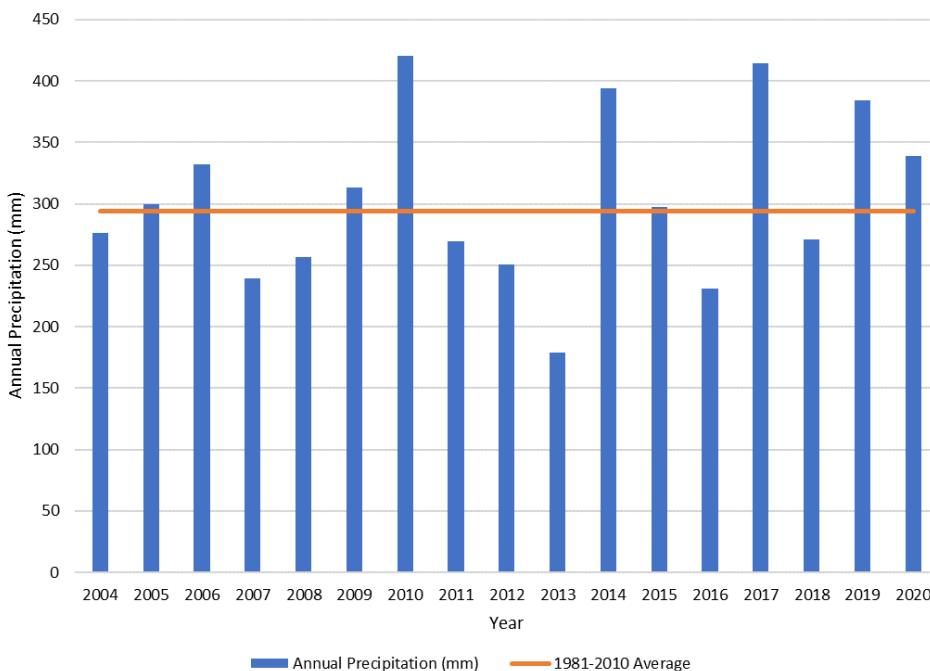


Figure 3. Annual and long-term average (1981-2010) precipitation for the Orchard Test Site, Idaho (PRISM 2021).

Daily high and low temperatures and long-term (1981-2010) monthly average minimum, mean, and maximum temperatures for the Orchard Test Site were obtained from PRISM (2021). Long-term monthly averages are shown in Figure 4. The coldest monthly mean minimum temperature,  $-6.1^{\circ}\text{C}$  ( $21^{\circ}\text{F}$ ), occurs in December, while the highest monthly mean maximum temperature,  $32.8^{\circ}\text{C}$  ( $91^{\circ}\text{F}$ ) occurs in July. For the period of this study, yearly extreme low temperatures for the Orchard Test Site ranged from  $-29^{\circ}\text{C}$  ( $-20^{\circ}\text{F}$ ) in 2017 to  $-12.5^{\circ}\text{C}$  ( $10^{\circ}\text{F}$ ) in 2020. Winter temperatures below  $-17^{\circ}\text{C}$  ( $0^{\circ}\text{F}$ ) occurred in over half the years of the study. Summer temperatures reached or exceeded  $38^{\circ}\text{C}$  ( $100^{\circ}\text{F}$ ) in every year of the study. The highest maximum temperature was  $44.2^{\circ}\text{C}$  ( $112^{\circ}\text{F}$ ) in 2013. Temperatures over  $42^{\circ}\text{C}$  ( $108^{\circ}\text{F}$ ) occurred in five years of the study.

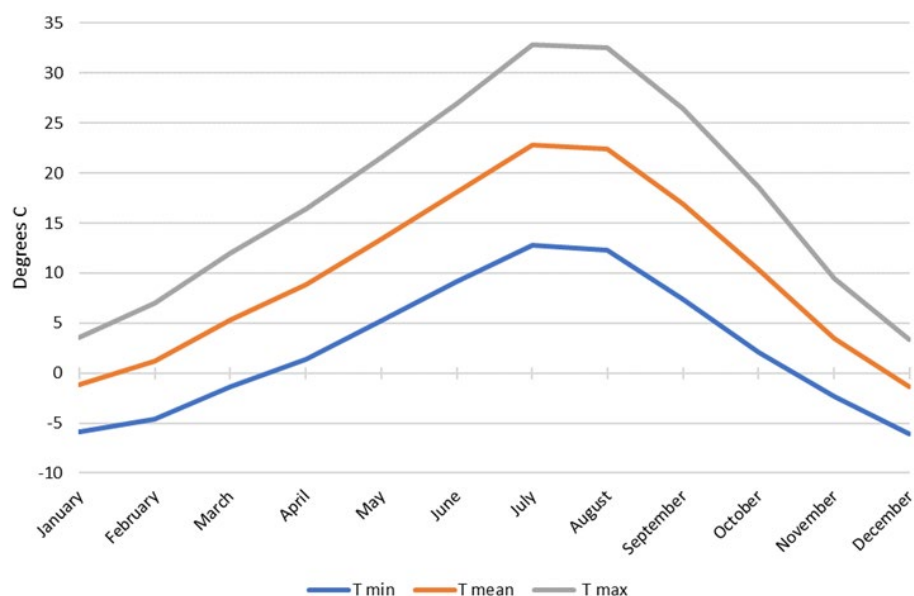


Figure 4. Monthly average maximum, minimum, and mean temperatures for the Orchard Test Site, Idaho (PRISM 2021).

## RESULTS

### 2005-2008

P-12, P-24 and Wahluke bluebunch wheatgrass accessions scored the highest average plant density in the establishment year with 17.2, 13.8, and 13.6 plants/m<sup>2</sup>, respectively (Figure 5). Snake River wheatgrass accession E-45 had the highest establishment of the species with 15.6 plants/m<sup>2</sup>. The lowest plant densities in the establishment year were from E-26 Snake River wheatgrass (2.2 plants/m<sup>2</sup>), along with Goldar and P-5 bluebunch wheatgrass with 4.0 and 6.6 plants/m<sup>2</sup>, respectively. In general, a decreasing trend of plant density was seen across most accessions from 2005 through 2008 with the greatest decrease in density occurring between the first and second years. Plant densities declined among all entries from 2005 to 2006 with the exception of Jim Creek bluebunch wheatgrass which remained constant at 11.0 plants/m<sup>2</sup>. Many accessions dropped significantly in density in the first year. For example, P-5 bluebunch wheatgrass decreased approximately 45% between 2005 and 2006. Following the declines in density in the first year of establishment, plant densities for most accessions remained somewhat steady between 2006 and 2008. In 2008, 4 years after establishment, the highest plant densities were observed among the Source Identified bluebunch wheatgrass releases Wahluke and Jim Creek (both 10.2 plants/m<sup>2</sup>).

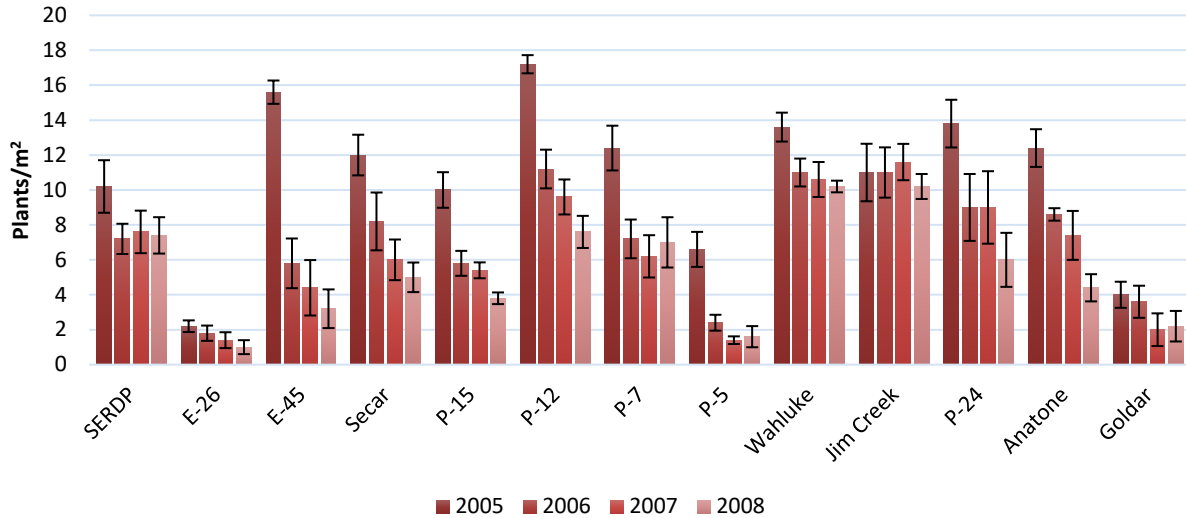


Figure 5. Average plant density of 13 bluebunch and Snake River wheatgrass accessions at Orchard, Idaho for years 2005-2008 derived from 5 pseudo replications within each non-replicated plot. Error bars indicate  $\pm 1$  standard error.

## 2021

Plant density data measured 16 years after planting varied from 1.2 to 7.4 plants/m<sup>2</sup> (Figure 6) indicating some entries may be better adapted to long term conditions at Orchard than others. Likewise, some releases showed superior long-term persistence than those which had better early establishment. Three entries, all bluebunch wheatgrass, had densities greater than 5 plants/m<sup>2</sup> after 16 years, P-24, Anatone and P-12 with 7.4, 6.8 and 5.4 plants/m<sup>2</sup>, respectively. Goldar, which is reputed to be better adapted to higher precipitation sites than other bluebunch releases (Ogle and others 2014) had lower density (4.6 plants/m<sup>2</sup>) than P-24 and P-12 but was similar in density to Anatone. Among Snake River wheatgrass accessions, Secar, SERDP and E-45 had mean densities of 5.0, 5.0 and 3.4, respectively. P-5, Wahluke, and E-26 had the lowest plant densities after 16 years with 1.2, 1.2 and 1.4 plants/m<sup>2</sup>, respectively.

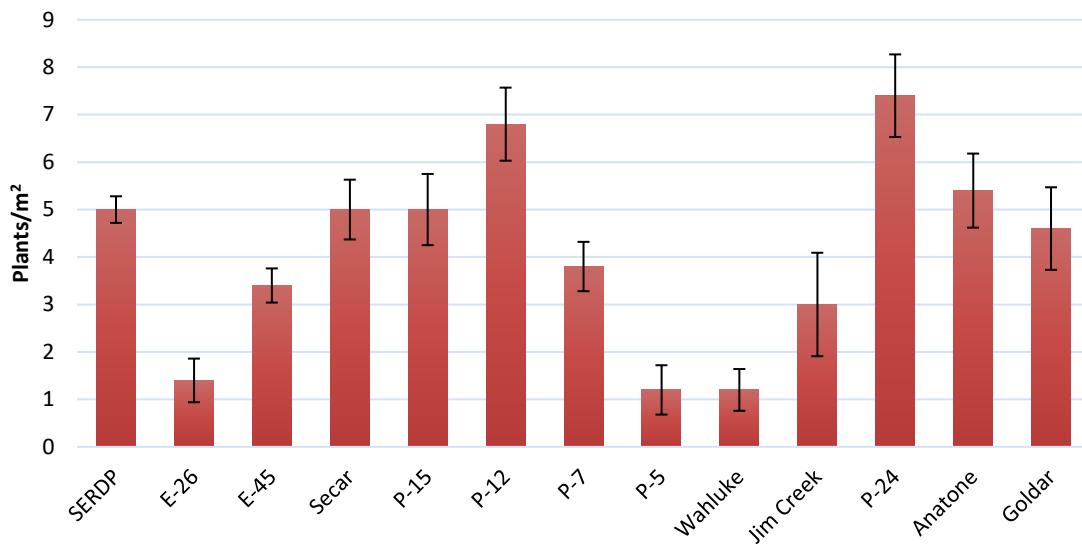


Figure 6. Plant densities of Snake River wheatgrass and bluebunch wheatgrass accessions in 2021, 16 years after planting. Error bars indicate  $\pm 1$  standard error.

NRCS guidelines indicate that suitable plant densities of rangeland seedings in sites with loamy soils receiving <300 mm (<12 in) mean annual precipitation should range between 5.4 and 16.1 plants/m<sup>2</sup> (0.5 to 1.5 plants/ft<sup>2</sup>) (Ogle and others 2011). Based on these parameters, numerous materials tested showed adequate densities for the first 4 years (SERDP, P-12, P-7, Wahluke, Jim Creek, P-24, and Anatone); however, only P-24, Anatone, and P-12 would be considered successful after 16 years. BLM Twin Falls District standards indicate a successful stand with >3 deep rooted perennial grasses/m<sup>2</sup> (Jirik 2022). Based on these criteria, all entries save E-26, P-5, and Wahluke would meet the standard of success after 16 years.

Percent cover values after 16 years averaged 24% among entries, ranging from as much as 44% (P-24) to a low of 8% (Wahluke and P-5) (Figure 7). Snake River wheatgrass accessions E-45 and E-26 appeared to have somewhat larger plants as indicated by low plant densities but relatively high percent cover. All entries save 2 (P-5 and Wahluke) had cover of greater than 20%.

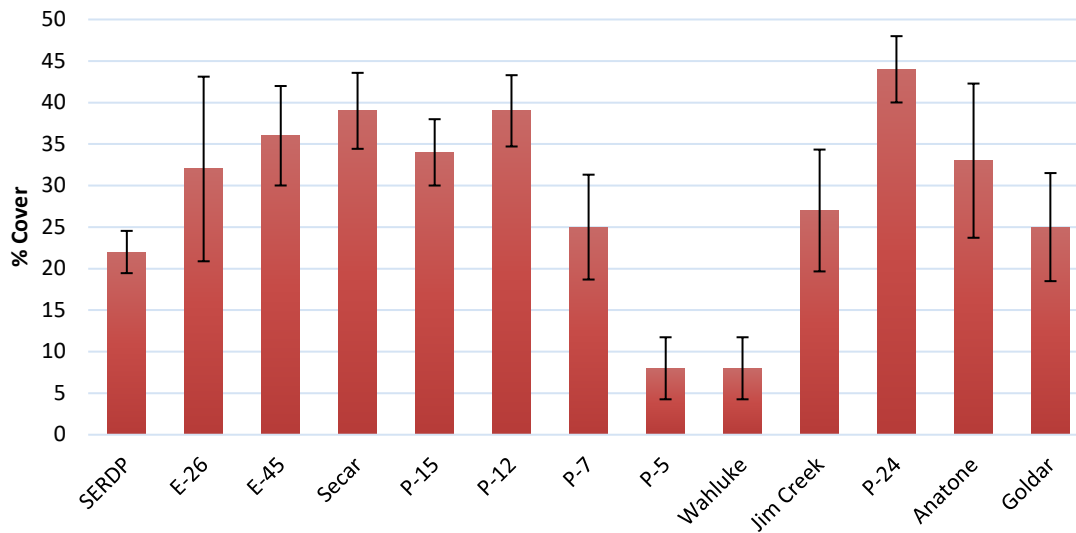


Figure 7. Canopy cover of Snake River wheatgrass and bluebunch wheatgrass accessions in 2021, 16 years after planting. Error bars indicate  $\pm 1$  standard error.

## DISCUSSION

St. Clair and others (2013) found released materials of bluebunch wheatgrass to be more vigorous, more reproductively fecund, and larger in stature when compared to local ecotypes at multiple common garden locations. Although no local Snake River Plain ecotypes were included in the Orchard display nursery, we found many bluebunch and Snake River wheatgrass germplasms from non-local origin to be adapted to establishing under local conditions. Plant materials considered to be adapted to long term stand persistence is dependent upon the standard used (NRCS or BLM). Numerous entries met BLM standards; however only 3 entries. P-24 and P-12, both precursors to Columbia germplasm bluebunch wheatgrass, and Anatone met NRCS requirements for a successful stand after 16 years.

Anatone originated in St. Clair and others (2013) transfer zone 6a, noted for large plants, early phenology and narrow leaves. However, this study indicates that although from a different seed transfer zone, this germplasm is well adapted to conditions at the Orchard site in the semiarid Snake River Plain (zone 3a-medium plant size, early phenology, and narrow leaf width). P-12 and P-24 originated from Adams County, WA in what falls in zone 3a. Based on St Clair and others (2013) seed transfer zones, these would be predicted to do well at Orchard, also a 3a site. However, P-12 and P-24 hail from what Massatti and others (2018) described as the Palouse/Wallowa genetic cluster, which was distinct from the Snake River Plain genotypes of the two Great Basin genetic clusters. This would indicate that while being from a distinctly different genetic cluster, materials from the Palouse/Wallowa cluster can be well adapted to the Snake River Plain.

Our results did not support the notion that Snake River wheatgrass is more drought tolerant or establishes better than bluebunch wheatgrass in semiarid rangeland. Establishment and persistence of Secar, the only formally released Snake River wheatgrass tested, was similar to that of bluebunch wheatgrass releases. Secar has been described as one of the most drought-tolerant native perennial grasses available, able to survive in sites receiving as little as 200 mm (7.9 in) of precipitation annually (Ogle and others 2002). Our results indicate that there are suitable bluebunch wheatgrass alternatives that perform equally well in semiarid conditions of southwestern Idaho where use of Snake River wheatgrass may be ecologically questionable, specifically on sites receiving greater than 290 mm (11.4 in) of annual precipitation.



*Figure 8. A healthy stand of bluebunch wheatgrass and Snake River wheatgrass at Orchard, ID 16 years after planting. Photo by Derek Tilley, NRCS.*

## CONCLUSION

We saw a wide range of plant density and canopy cover at the Orchard Test Site, both long- and short-term, for the various entries indicating a range of phenotypes of both species (Figure 8). We found evidence of bluebunch and Snake River wheatgrass accessions and releases adapted to the long-term site conditions, despite originating from distinctly different recommended seed transfer zones and genetic clusters than the planting site. Our results further support the idea that Anatone bluebunch wheatgrass may be better adapted to lower precipitation areas than Goldar. We did not see evidence that Snake River wheatgrass was more drought tolerant than bluebunch releases at the Orchard study site, but rather we saw significant variation between releases or accessions. Greater differences in adaptation between the two species may be more apparent at lower precipitation sites. More long-term studies examining adaptation of specific germplasm sources to a range of environmental conditions of the various seed zones or ecoregions are needed to elucidate the

adaptive distinctions between releases.

### LITERATURE CITED

- Alderson J, Sharp WC. 1994. Grass Varieties in the United States. USDA Soil Conservation Service, Ag. Handbook No. 170. 296 p.
- Aubry C, Shoal R, Erickson V. 2005. Grass cultivars: their origins, development, and use on national forests and grasslands in the Pacific Northwest. USDA Forest Service. Olympia, WA. 55 p.
- Barkworth ME, Carlson JR. 1997. *Elymus wawawaiensis*: A species hitherto confused with *Pseudoroegneria spicata* (Triticeae, Poaceae). *Phytologia* 83:312-330.
- BFI Native Seeds. 2021. <http://bfinativeseeds.com> (accessed 12 April 2021). Moses Lake (WA).
- Caldwell MM. 1985. Cold desert. In: Chabot BF, Mooney HA, editors. *Physiological Ecology of North American Plant Communities*. New York: Chapman and Hall. p. 198-212.
- Comstock JP, Ehleringer JR. 1992. Plant adaptation in the Great Basin and Colorado Plateau. *Great Basin Naturalist* 52(3):195-215.
- Darris D. 2001. 'Arlington' and 'Elkton' blue wildrye. USDA Natural Resources Conservation Service. Corvallis (OR). 2 p.
- DePue JA, Englert JM. 2015. Improved Conservation Plant Materials Released by NRCS and Cooperators through December 2014. Beltsville (MD): USDA Natural Resources Conservation Service. 71 p.
- Gunnell K. 2021. Personal communication. Ephraim (UT): Utah Division of Wildlife Resources. Great Basin Research Center. GRBC Coordinator.
- Jensen S, Anderson VJ, Christensen W, Roundy B, Kitchen S, Allphin L. 2020. Does basin wildrye (*Leymus cinereus*) show local adaptation when deployed according to generalized seed zones in the Central Basin and Range ecoregion? *Native Plants Journal* 22(2): 112-122.
- Jirik S. 2022. Personal communication. Boise (ID): USDI Bureau of Land Management. Post Fire Recovery & Noxious Weed Program Lead.
- Johnson RC, Helier BC, Vance-Borland KW. 2013. Genecology and seed zones for tapertip onion in the US Great Basin. *Botany* 91:686-694.
- Jones, TA. 2021. Personal communication. Logan (UT): USDA Agricultural Research Service. Forage and Range Research Laboratory. Research Geneticist (Plants).
- Jones TA, Johnson DA. 1998. Integrating genetic concepts into planning rangeland seedings. *Journal of Range Management* 51(6):594-606.
- Jones TA, Larson SR, Nielson DC, Young SA, Chatterton NJ, Palazzo AJ. 2002. Registration of P-7 bluebunch wheatgrass germplasm. *Crop Science* 42(5):1754-1755.
- Jones TA, Mott IW. 2016. Notice of release of Columbia Germplasm of bluebunch wheatgrass. *Native Plants Journal* 17(1):53-58.
- Kramer AT, Larkin DJ, Fant JB. 2015. Assessing potential seed transfer zones for five forb species from the Great Basin Floristic Region. *Natural Areas Journal* 35(1):174-188.
- LeFebvre J, Scianna J, Pokorny M. 2017. Notice of release of Stucky Ridge Germplasm silverleaf Phacelia. USDA Natural Resources Conservation Service. Bridger (MT). 10 p.
- Massatti R, Prendeville HR, Larson S, Richardson BA, Waldron B, Kilkenny FF. 2018. Population history provides foundational knowledge for utilizing and developing native plant restoration materials. *Evolutionary Applications* 11:2025-2039.
- McKay JK, Christian CE, Harrison S, Rice KJ. "How local is local?"-A review of practical and conceptual issues in the genetics of restoration. *Restoration Ecology* 13(3):432-440.
- Monsen SB, Kitchen SG, Memmott K, Shaw N, Pellant M, Young S, Ogle D, St. John L. 2003.

- Notice to release Anatone germplasm bluebunch wheatgrass (selected class natural population). Provo (UT): USFS Rocky Mountain Research Station, Shrub Sciences Laboratory. 45 p.
- Ogle DG, St. John L, Jones TA. 2010. Plant Guide for bluebunch wheatgrass (*Pseudoroegneria spicata*). Boise (ID): USDA Natural Resources Conservation Service. 5 p.
- Ogle D, St. John L, Stannard M, Brazee B. 2011. Guidelines for determining stand establishment on pasture, range and conservation seedings. Technical Note No. 12. Boise (ID): USDA Natural Resources Conservation Service, 8p.
- Ogle D, St. John L, Stannard M, Holzworth L. 2011. Grass, grass-like, forb, legume and woody species for the Intermountain West. Technical Note No. 24. Boise, (ID), Bozeman (MT), Spokane (WA): USDA Natural Resources Conservation Service. 41p.
- Ogle D, Stannard M, Jones TA. 2002. Plant Guide for Snake River wheatgrass (*Elymus wawawaiensis*). Boise (ID): USDA Natural Resources Conservation Service. 4p.
- Pilliod DS, Welty JL, Toevs GR. 2017. Seventy-five years of vegetation treatments on public rangelands in the Great Basin of North America. *Rangelands* 39(1):1-9.
- [PRISM] Parameter-elevation Regressions on Independent Slopes Model. 2021. PRISM Climate Group, Oregon State University, <http://prism.oregonstate.edu> (accessed 19 October 2021).
- Smith SD, Monson RK, Anderson JE. 2012. *Physiological Ecology of North American Desert Plants*. Springer Science and Business Media. 288 p.
- St. Clair JB, Kilkenny F, Johnson R, Shaw N, Weaver G. 2013. Genetic variation in adaptive traits and transfer zones for *Pseudoroegneria spicata* (bluebunch wheatgrass) in the northwestern United States. *Evolutionary Applications* 6(3):933-948.
- St. John L, Ogle D, Tilley D, Majerus M, Holzworth L. 2005. Mixing seed with rice hulls. Technical Note No. 7, Boise (ID): USDA-Natural Resources Conservation Service. 14p.
- Tilley DJ. 2015. Notice of release of Amethyst Germplasm hoary tansyaster: selected class of natural germplasm. *Native Plants Journal* 16(1):54–60. <https://doi.org/10.3368/npj.16.1.54>
- [USDA FS] USDA Forest Service. 1937. *Range Plant Handbook*. U.S. Govt. Printing Office. Washington, D.C.
- McNab WH. 1996. *Ecological Subregions of the United States*. USDA Forest Service. <https://www.fs.fed.us/land/pubs/ecoregions/ch48.html> (accessed 9 August 2022).
- [USDA NRCS] USDA Natural Resources Conservation Service. 2004. Notice of release of Newberry Germplasm Indiangrass. Jimmy Carter Plant Materials Center. Americus (GA). 21p.
- [USDA NRCS] USDA Natural Resources Conservation Service. 2010. *National Plant Materials Manual Fourth Edition*. Washington (DC). 380 p.
- [USDA NRCS] USDA Natural Resources Conservation Service. 2021a. Custom Soil Resource Report for Ada County Area. Web Soil Survey. <https://websoilsurvey.sc.egov.usda.gov/> (accessed 8 April 2021).
- [USDA NRCS] USDA Natural Resources Conservation Service. 2021b. Field Office Technical Guide. <https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/fotg/> (accessed 9 April 2021).
- [USDA NRCS] USDA Natural Resources Conservation Service. 2022. The PLANTS Database. URL: <http://plants.usda.gov> (accessed 9 September 2020) Greensboro (NC): National Plant Data Team
- [USDA SCS] USDA Soil Conservation Service. 1989. Notice of release of ‘Goldar’ bluebunch wheatgrass. Boise (ID). 7 p.

In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at [How to File a Program Discrimination Complaint](#) and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: [program.intake@usda.gov](mailto:program.intake@usda.gov).

USDA is an equal opportunity provider, employer, and lender.

*Helping People Help the Land*