'Vavilov II', a New Siberian Wheatgrass Cultivar with Improved Persistence and Establishment on Rangelands

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ABSTRACT

'Vavilov II' Siberian wheatgrass [*Agropyron fragile* (Roth) Candargy] (Reg. No. CV-30, PI 653686) was released by the USDA-ARS, the U.S. Army-Engineer Research and Development Center, Utah Agricultural Experiment Station, and the USDA-NRCS. Vavilov II was developed for reseeding sandy soils on disturbed rangelands dominated by annual weeds as a result of severe disturbance, frequent fires, and soil erosion. Selection emphasis in Vavilov II was on seedling establishment and stand persistence. During the establishment year, Vavilov II had increased numbers of seedlings per unit area (m^2) using a frequency grid than 'Vavilov' at Yakima, WA, Fillmore, UT, Dugway, UT, and Curlew Valley, ID. Vavilov II was more persistent than Vavilov at Yakima, WA, Fillmore, UT, Curlew Valley, ID, and Malta, ID. Foundation seed of Vavilov II is available through the Utah Crop Improvement Association and the University of Idaho Foundation Seed Program.

Vast areas of semiarid rangeland in the western United States are severely disturbed, frequently burned, increasingly eroded, and subsequently infested with troublesome weeds such as cheatgrass (*Bromus tectorum* L.), medusahead [*Taeniatherum caput-medusae* (L.) Nevski], and others. Reseeding disturbed rangelands with genetically improved plant materials that are competitive enough (i.e., seedling establishment and persistence) to replace existing undesirable vegetation is often the most plausible and economically feasible way to reclaim such sites (Asay et al., 2003). A failure to develop improved plant materials that can restore these degraded rangelands to perennial vegetation will result in increased fire frequency, loss of soil structure (Norton et al., 2004), increased soil erosion, and economically unproductive rangelands. One species frequently used in rangeland revegetation is Siberian wheatgrass [*Agropyron fragile* (Roth) Candargy].

In its native habitat, Siberian wheatgrass is more drought resistant and better adapted to medium to coarse textured soils than either Standard [*A. desertorum* (Fisch. ex Link) Schultes] or Fairway (*A. cristatum* L.) type crested wheatgrass. Siberian wheatgrass is recommended for semiarid ecological sites receiving between 150 and 300 mm of annual precipitation at elevations up to 2150 m. When drilled under dryland range conditions, a seeding rate of 8 kg ha^{-1} is recommended (Jensen et al., 2001). In recent studies on six ecological sites, Siberian wheatgrass was one of the easiest species to establish and was more productive, more persistent, and more defoliation tolerant under severe water stress compared with other rangeland grasses (Asay et al., 2001).

'P-27', the first released Siberian wheatgrass cultivar, was released in 1953 by the NRCS and was selected for persistence from a large evaluation nursery (Alderson and Sharp, 1994). At present, the most widely used Siberian wheatgrass cultivar is 'Vavilov', which was released in 1994 and exhibits increased retention of plant color, vegetative vigor under extreme drought, seedling establishment, and seed yield compared with P-27 (Asay et al., 1995). To combat the increasing spread of invasive annual weeds on western

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Abbreviations: AFLP, amplified fragment length polymorphism; DMY, dry matter yield; NPGS, National Plant Germplasm System; PAUP, phylogenetic analysis using parsimony; UPGMA, unweighted pair group method with arithmetic mean.

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rangelands, it is critical to develop improved plant materials with increased seedling establishment and persistence (Asay et al., 2003). The principle objective of this research was to develop a Siberian wheatgrass cultivar with increased establishment and persistence characteristics under harsh, dry environments of the western United States.

'Vavilov II' Siberian wheatgrass (Reg. No. CV-30, PI 653686) was released by the USDA-ARS, the U.S. Army Corps of Engineers-Engineer Research and Development Center, Utah Agricultural Experiment Station, Utah State University, and the USDA-NRCS. Developed for use on arid and semiarid rangelands as a rapidly establishing revegetation grass in the Intermountain West, Great Basin, and Northern Great Plains regions of western United States (Ogle et al., 2007; St. John, 2008). Vavilov II was evaluated in field trials as Vavilov-Select, SERDP Siberian wheatgrass, and 9076515 (NRCS). Vavilov II is a broad-based 50-clone synthetic that was developed and tested as part of the Strategic Environmental Research and Development Program project CS-1103 to identify resilient plant characteristics and develop wear-resistant plant cultivars(s) for use on military training lands. Vavilov II was selected for stand persistence and seedling establishment in response to drought. Vavilov II expands the genetic base of Vavilov, has been evaluated extensively on ecological sites in the western United States, and has superior seedling establishment and stand persistence compared with Vavilov.

Methods

Breeding History

The parent material for Vavilov II Siberian wheatgrass was selected from evaluation trials at three locations: Yakima, WA, Curlew Valley, ID, and Lakeside, UT. At Yakima, an 832-plant nursery of Vavilov was established in 1998. On the basis of visual plant vigor, total seed yield, and seedling establishment (ability to emerge from a 7.6-cm planting depth in a greenhouse) in 1999, 15 genotypes were selected from this nursery. At Curlew Valley (USDA-Forest Service, Curlew National Grasslands), an evaluation nursery was established in 1998 and included Vavilov and collections made from the steppes of Kazakhstan in 1988 by Drs. Kay Asay and Douglas Johnson. Based on visual plant vigor, five genotypes from Vavilov and one from the steppes of Kazakhstan (PI 598668) were selected. At Lakeside, Vavilov and two bulk populations (low and medium annual precipitation) from Kazakhstan were evaluated. The low annual precipitation population originated by equal bulking by weight of original seed from PIs 598682, 598683, 598684, 598685, 598686, 598687, 632475 and collection JA 68 that originated from sites that received annual precipitation ranging from 100 to 130 mm (Jensen et al., 2008). The medium annual precipitation population originated by equal bulking by weight of original seed from PIs 598664, 598665, 598666, 598667, 598689, 598690, 598691, 598692, 598693, 598694, 598696, 598697, 598698, 598714, 598715 and collection JA 74 that originated from sites that received annual precipitation of 150 mm (Jensen et al., 2008). Twenty-one genotypes from Vavilov and eight genotypes from the Kazakhstan collection (four each from the different annual precipitation populations) were selected from the Lakeside site.

Twenty vegetative propagules from each of 50 genotypes selected from Yakima, Curlew Valley, and Lakeside, UT, were established in 2000 at the Blue Creek, UT, research station and designated as the Vavilov II Breeder seed.

Seeded Trials

Between 2002 and 2005, fall-seeded evaluation trials were established to compare seedling establishment and persistence of Vavilov II and Vavilov at Yakima, WA (46°50´47˝ N, 120°22´18˝ W; elevation 704 m; 20 cm annual precipitation); Guernsey, WY (42°15´46˝ N, 104°48´01˝ W; elevation 1429 m; 31 cm annual precipitation); Fillmore, UT (39°10´50˝ N, 112°14´27˝ W; elevation 1769 m; 18 cm annual precipitation); Curlew Valley, ID (42°01´15˝ N, 112°39´09˝ W; elevation 1432 m; 23 cm annual precipitation); Malta, ID (42°14´21˝ N, 113°08´09˝ W; elevation 1650 m; 18 cm annual precipitation), and Dugway, UT (40°15´51˝ N, 112°49´06˝ W; elevation 1614 m; 15 cm annual precipitation). Plots in each trial were arranged in a randomized complete block with four replications. Entries were seeded at a rate of one pure live seed cm^{-1} at a seeding depth of 0.63 cm in five rows. Plot size was 1.5 m wide by 8 m long.

The NRCS planted Vavilov II along with 58 accessions of grasses, forbs, and shrubs in a fall-dormant planting in November 2007 at Coffee Point, ID (43°09´19˝ N, 112°57´59˝ W; elevation 1475 m; 13 cm annual precipitation). Seedling establishment data were collected using a frequency grid on 1 May 2007 and 7 Sept. 2007.

Seedling Establishment

Seedling establishment and persistence were measured as plant density frequency using the grid system described by Vogel and Masters (2001). Frequency was determined by laying a grid of 5.1- by 5.1-cm quadrants over the drilled rows and determining the percentage of quadrants containing at least one seedling. If a plant occurred in every quadrant, establishment was considered to be 100%. This was repeated three times along the 8-m row for a total of 144 quadrants. The same procedure was used to determine stand persistence except that the quadrants were 10.2- by 10.2-cm for a total 72 quadrants per plot. All data were subjected to analysis of variance using GLM procedures as a fixed model. Unless otherwise noted, all mean separations were made on the basis of least significant differences at the 0.05 probability level (SAS Institute, 1999).

Morphological Characterization

Twelve morphological characters were measured from at least 40 different plants each of Vavilov II, Vavilov, and P-27 at Nephi (39°38´43˝ N, 111°52´11˝ W; elevation 1600 m) and Blue Creek (41°56´02˝ N, 112°26´20˝ W; elevation 1563 m), UT. The experimental design at each location was an RCBD with four replications at Nephi and six replications at Bluecreek with 10 plants per replication. Genotype × environment interactions were only significant for 2 of the 12 morphological traits measured; thus, the morphological data is presented as combined across locations.

Molecular Characterization

Twelve plants from each of four Siberian wheatgrass cultivars or breeding populations, Vavilov II; Vavilov; P-27; and a population originating from the JA collections called Kazak were screened for DNA polymorphisms with six Amplified fragment length polymorphism (AFLP) primer pairs: E.AGC_M.CAG, E.AGC_M.CAT, E.AGC_M.CTG, E.AGG_M.CAA, E.AGG_M.CAC, and E.AGG_M.CAG. Amplified fragment length polymorphism reactions were conducted according to Vos et al. (1995), except that fluorescently labeled primers were used and detected on an ABI3730 (Applied Biosystems, Foster City, CA). Size standards were spiked into each reaction to assure band-length validity. Estimates of similarity were obtained using the method described by Leonard et al. (1999), and analysis of molecular variance and diversity were estimated as per Excoffier et al. (1992). Dendograms were constructed using unweighted pair group method with arithmetic mean (UPGMA) cluster methods in PAUP (Swofford, 2001).

Characteristics

Seedling Establishment

Rapid seedling establishment is one of the primary keys to successful revegetation in the western United States. Vavilov II had more seedlings per unit area (m^2) during the establishment year than Vavilov at Yakima, WA (52 vs. 23%); Fillmore, UT (79 vs. 54%); Dugway, UT (33 vs. 18%); and Curlew Valley, ID (70 vs. 40%) (Table 1). Vavilov II was more persistent after establishment, as measured by percentage, stand than Vavilov at Yakima, WA (68 vs. 44%); Fillmore, UT (84 vs. 62%); Curlew Valley, ID (69 vs. 55%); and Malta, ID (97 vs. 91%) (Table 2). Dry matter yields (64- by 38-cm plot) combined across Yakima, WA, and Guernsey, WY, were significantly ($p < 0.05$) greater in Vavilov II (53 g plot^{-1}) than Vavilov (39 g plot^{-1}). Vavilov II germinated in 7 d compared with 10 d for Vavilov on sandy loam, loam, and sandy soil types.

At the Coffee Point site, Vavilov II had the highest seedling establishment of all accessions evaluated at 15.9 plants m^{-2} compared with 8.0 plants m^{-2} for Vavilov on 1 May 2007. On 7 Sept. 2007, Vavilov II had 15.7 plants m^{-2} and Vavilov had 7.4 plants m^{-2}. The development of Vavilov II gives land managers new plant materials with enhanced seedling establishment and persistence on dry harsh rangelands.

Table 1. Stand establishment (% stand) of 'Vavilov II' Siberian wheatgrass compared with 'Vavilov' at six locations.

Entry	Stand establishment					
	Yakima, WA	Guernsey, WY	Fillmore, UT	Curlew Valley, ID	Malta, ID	Dugway, UT
	%					
Vavilov II	52	54	79	70	95	33
Vavilov	23	38†	54	40	92	18
$LSD_{0.05}$	16	20	17	12	5	10

†Significant at the $P < 0.10$ level.

Table 2. Stand persistence (% stand) of 'Vavilov II' Siberian wheatgrass compared with 'Vavilov' at five locations.

Entry	Stand persistence				
	Yakima, WA	Guernsey, WY	Fillmore, UT	Curlew Valley, ID	Malta, ID
	%				
Vavilov II	68	61	84	69	97
Vavilov	44	50†	62	55	91
$LSD_{0.05}$	22	19	21	9	5

†Significant at the $P < 0.10$ level.

Morphological Characterization

With the exception of flag leaf height and glume length, genotype × environment interactions were not significant (Table 3) in the combined analysis. Within locations, the rankings for Vavilov II, Vavilov, and P-27 remained the same. Contributing to this interaction was a magnitude shift, with flag leaf height averaging 16 cm higher at Nephi than at Bluecreek. There was a rank change for glume length between locations. Vavilov II continued to have the longest glumes, while Vavilov and P-27 changed order at the different locations. When combined across locations (Nephi and Blue Creek, UT) (Table 3), Vavilov II has shorter flag leaves (10.2 cm) than Vavilov (11.7 cm) but longer leaves than P-27 (8.5 cm). Spikes of Vavilov II were shorter (8.2 cm) than Vavilov (9.1 cm) but similar to P-27 (7.8). Vavilov II was taller (64.2 cm) than P-27 (58.2 cm) but similar in plant height to Vavilov (63.4 cm). Flag leaves in Vavilov II were oriented higher on the culm (40.3 cm) and were wider (3.1 mm) than P-27. Vavilov II has longer lemmas than P-27 but was similar to Vavilov. Lemma and glume awn lengths in Vavilov II were longer than P-27. Nondiagnostic morphological traits included spike width, lemma width, glume width, and spike length–to–spike width ratio. Heading and flowering dates at Blue Creek and Nephi, UT, were the third week in May and first week in June, respectively. Vavilov II is an autotetraploid ($2n = 4x = 28$; PPPP) and has the same ploidy level and genomic composition as P-27 and Vavilov.

Molecular Characterization

Amplified fragment length polymorphisms were used to compare Vavilov II to Vavilov, P-27, and a breeding population Kazak Siberian wheatgrass. The six AFLP primer pairs amplified 728 bands that were present in more than 5% and less than 95% of the individuals. The average number of AFLP bands ranged from 239 for P27 to 255 for Kazak Siberian wheatgrass and Vavilov II. The average number of pairwise differences within the different populations ranged from 203 to 218 bands, while the average number of pairwise differences between populations was 226 to 247 bands. Across the three cultivars and a breeding population, 88% of variation was within, while 12% was between. The most similar cultivars were Vavilov and Vavilov II. The results are consistent with the pedigree of the three cultivars and breeding population. A dendogram was generated using cluster analysis (UPGMA) based on the average pairwise differences between the populations (Fig. 1).

Table. 3. Morphological summary of morphological traits combined across Nephi and Blue Creek, UT (planted April 2004).

Morphological traits		Vavilov II	Vavilov	P-27	$LSD_{0.05}$
Plant height (cm)	Mean	64.2	63.4	58.2	3.7
	Range	38.5–130.2	26.0–100.2	35.0–87.3	
Flag leaf height (cm)	Mean	40.3	39.3	34.0	3.3†
	Range	15.1–68.2	7.0–63.5	11.4–55.8	
Flag leaf length (cm)	Mean	10.2	11.7	8.5	0.8
	Range	3.2–21.0	4.0–24.7	2.5–22.0	
Flag leaf width (mm)	Mean	3.1	2.8	2.6	0.4
	Range	1.5–6.0	2.0–5.0	1.0–6.0	
Spike length (cm)	Mean	8.2	9.1	7.8	0.7
	Range	5.0–12.5	4.8–22.4	4.0–18.1	
First lemma length (mm)	Mean	7.4	7.2	6.4	0.4
	Range	5.0–12.0	4.5–10.5	5.0–12.0	
First lemma awn length (mm)	Mean	0.9	0.8	0.4	0.3
	Range	0.0–4.0	0.0–3.5	0.0–4.5	
First glume length (mm)	Mean	6.1	5.8	5.4	0.5
	Range	3.0–10.0	3.5–9.0	2.2–9.5	
First glume awn length (mm)	Mean	1.9	1.7	1.2	0.4†
	Range	0.0–6.0	0.0–4.5	0.0–4.5	

†Traits with significant ($P < 0.05$) genotype × environment interaction.

Availability

A Foundation seed production field was established at the Aberdeen Plant Materials Center in August 2005. In 2006, seed was harvested from the field and yielded 748 kg (740 kg ha^{-1}). Breeder, Foundation, Registered, and Certified seed classes will be recognized. Breeder and Foundation seed will be maintained by the USDA-ARS Forage and Range Research Laboratory at Logan, UT, and the USDA-NRCS Plant Materials Center at Aberdeen, ID. Protection under the U.S. Plant Variety Protection Act of 1994 will be applied for, with the requirement that seed of Vavilov II can be marketed only as a class of Certified seed. No seed will be distributed without written permission for 20 yr from the date of release, 11 Mar. 2008, by the USDA-ARS, at which time seed will also be available from the National Plant Germplasm System. Foundation seed is available through the following contacts: Utah Crop Improvement Association (435-797-2082; sayoung@mendel.usu.edu) and University of Idaho Foundation Seed Program (208-423-6655; Williams@kimberly.uidaho.edu).

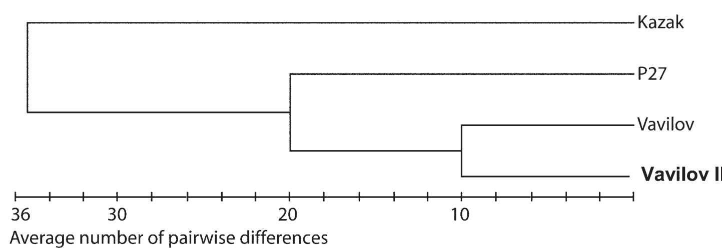

Figure 1. Unweighted pair group method with arithmetic mean cluster analysis of the average pairwise differences among three Siberian wheatgrass cultivars and a breeding population. Twelve plants per accession were used in the analysis.

References

Alderson, J., and W.C. Sharp. 1994. Grass varieties in the United States. USDA Agric. Handbook 170. U.S. Gov. Print. Office, Washington, DC.

Asay, K.H., N.J. Chatterton, K.B. Jensen, T.A. Jones, B.L. Waldron, and W.H. Horton. 2003. Breeding improved grasses for semiarid rangelands. Arid Land Res. Manage. 17:469–478.

Asay, K.H., W.H. Horton, K.B. Jensen, and A.J. Palazzo. 2001. Merits of native and introduced Triticeae grasses on semiarid rangelands. Can. J. Plant Sci. 81:45–52.

Asay, K.H., D.A. Johnson, K.B. Jensen, N.J. Chatterton, W.H. Horton, W.T. Hansen, and S.A. Young. 1995. Registration of Vavilov Siberian crested wheatgrass. Crop Sci. 35:1510.

Excoffier, L., P.E. Smouse, and J.M. Quattro. 1992. Analysis of molecular variance inferred from metric distances among DNA haplotypes: Application to the human mitochondrial DNA restriction data. Genetics 131:479–491.

Jensen, K.B., W.H. Horton, R. Reed, and R.E. Whitesides. 2001. Intermountain planting guide. Experiment No. AG510. Utah State Univ. Extension Publications, Logan.

Jensen, K.B., A.J. Palazzo, B.L. Waldron, B.S. Bushman, D. Ogle, L. St. John, and J. Griggs. 2008. Release notice of Vavilov II Siberian wheatgrass.

Leonard, A.C., S.E. Franson, V.S. Hertzberg, M.K. Smith, and G.P. Toth. 1999. Hypothesis testing with the similarity index. Mol. Ecol. 8:2105–2114.

Norton, J.B., T.A. Monaco, J.M. Norton, D.A. Johnson, and T.A. Jones. 2004. Cheatgrass invasion alters soil morphology and organic mater dynamics in big sagebrush–steppe rangelands. p. 57–63. *In* A.L. Hild, N.L. Shaw, S.E. Meyer, D.T. Booth, and E.D. McArthur (ed.) Proceedings: Seed and Soil Dynamics in Shrubland Ecosystems, Laramie, WY. 12–16 Aug. 2002. Proc. RMRS-P-31. USDA, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Ogle, D.G., L. St. John, and K.B. Jensen. 2007. Siberian wheatgrass plant guide. Available at http://plants.usda.gov/plantguide/doc/pg_agfr.doc (verified 28 Oct. 2008). USDA-NRCS, Washington, DC.

SAS Institute. 1999. SAS/STAT users guide. Version 6. 4th ed. SAS Inst., Cary, NC.

St. John, L. 2008. Vavilov II Siberian wheatgrass plant release brochure. USDA-NRCS, Boise, ID.

Swofford, D.L. 2001. PAUP*: Phylogenetic analysis using parsimony. Sinauer, Sunderland, MA.

Vogel, K.P., and R.A. Masters. 2001. Frequency grid: A simple tool for measuring grassland establishment. J. Range Manage. 54:653–655.

Vos, P., R. Hogers, M. Bleeker, M. Reijans, T. Van de Lee, M. Hornes, A. Frijters, L. Pot, J. Peleman, M.A. Kuiper, and M. Zabeau. 1995. AFLP: A new technique for DNA fingerprinting. Nucleic Acids Res. 23:4407–4414.