USDA-ARS Multicolored Ornamental *Festuca* Grass Cultivars “Freedom Fire” ‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’ for Low-input Applications in Semiarid Environments

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Over half of the world’s population lives in an urban setting (Worldwatch Institute, 2007), where ornamental plants provide environments that encourage the presence of wildlife and plant diversity (Damschen et al., 2006) and offer a myriad of social and economic benefits (Lohr et al., 2007; Wolf, 2004). However, continued reduction in limited natural resources worldwide increasingly necessitates novel approaches for the incorporation of low maintenance and low-input plant materials into urban landscapes (Cook, 1996; Dewey et al., 2006).

The popularity of ornamental grasses for use in urban landscapes, parks, median strips, parking lot borders, and for erosion control on slopes has increased in recent years (Loram et al., 2008; Wilson and Knox, 2006). Although native and nonnative grasses are considered central to many U.S. urban landscapes (Beard and Green, 1994; Fender, 2006), there is an increasing consumer demand for low-input naturally occurring grass species for various horticultural applications, especially in semiarid regions of the western United States (Dewey et al., 2006; Thetford et al., 2009). In such regions (USDA hardiness zones 3–5; annual precipitation 254–610 mm) relatively short-statured (15–30 cm tall) perennial grasses such as little bluestem [*Schizachyrium scoparium* (Michx.) Nash], Western wheatgrass [*Pascopyrum smithii* (Rydb.) A. Love; synonym. *Agropyron smithii* (Rydb.) Barkworth &

D.R. Dewey], prairie Junegrass [*Koeleria macrantha* (Ledeb.) Schult.; synonym. *K. cristata* auct.], needle grass [*Stipa spartea* (Trin.) Barkworth], buffalo grass [*Buchloe dactyloides* (Nutt.) Engelm.], and blue grama [*Bouteloua gracilis* (Kunth) Lag. ex Griffiths] are being increasingly used for low-input urban horticultural applications (Wilson, 2011).

Drought tolerant, tall-statured (>40 cm tall), western U.S. indigenous grasses with intense multicolored culms and panicles are not commercially available for low-input ornamental applications. The genus *Festuca* contains about 300 genetically diverse, wide- and narrow-leaved perennial, tufted and rhizomatous grass species, of which several possess drought tolerance and have attributes useful for low-input applications (Ruemmele et al., 2003). For instance, some fine-leaved *Festuca* species [e.g., *F. rubra* var. *commutata* Gaud.; *F. ovina* var. *duriuscula* (L.) Koch] remain relatively green under high temperatures (e.g., >30 °C) and drought conditions, and have been useful for a variety of turf applications (Aronson et al., 1987; Ruemmele et al., 2003). In 1982, the U.S. Natural Resources Conservation Services (NRCS) Bridger Plant Materials Center (BPMC) collected seed from an indigenous fine-leaved *Festuca* population in a semiarid region near Busby, MT, and designated it FEID 9025897. This population possesses tall-statured genotypes with multicolored stems (Staub et al., 2014) and is the source for the naturally occurring ornamental *Festuca* germplasms described herein for use in semiarid growing environments.

Origin

Seed of FEID 9025897 was originally collected (>10 plants) by the BPMC on the Charles E. Helvey Ranch east of the Rosebud River (T7S R39E NW1/4Sec 3; 45°31'39"N

lat., 106°58'25" W long.) in Big Horn County, MT. The seed of the initially collected population was field increased by the NRCS-BPMC in 1994 and was received by the USDA-ARS Forage and Range Research Laboratory (FRRL) in 2004. Although the ancestry of plants in this population is unknown, indigenous, fine-leaved *F. ovina* L. (2x; sheep fescue), and *F. idahoensis* L. (4x; Idaho fescue) populations exist throughout this region of Montana (Barkworth et al., 2007) and, thus, could be progenitors of FEID 9025897. Therefore, in 2006, a preliminary molecular analysis of this population (five plants) was conducted by the FRRL using amplified fragment length polymorphism (AFLP) markers to characterize its genetic relatedness to other *Festuca* species. Data indicated that FEID 9025897 plants possessed relatively close genetic similarities with *F. ovina* L. (sheep fescue) (Jones et al., 2008). In 2009, a visual inspection of 270 FEID 9025897 cloned plants examined under replication in a Logan UT field nursery showed that the vast majority (>98%) were sterile (degenerated pistils and stamens) (Staub et al., 2014). Moreover, subsequent broad-based AFLP and cytogenetic examinations of these FEID 9025897 plants indicated that this population likely originated from a naturalized mating between *F. idahoensis* (4x) and *F. ovina* (2x), resulting in partially and fully sterile triploid (3x) and possibly aneuploid progeny (Staub et al., 2014).

Plant Evaluation

Of the 270 plants examined by Staub et al. (2014), 19 were comparatively vigorous, relatively tall, and possessed multicolored culms suggesting their potential for low-input western U.S. urban horticultural applications. These 19 plants were lifted from a field and cloned in the greenhouse to compare their cytology, genetic structure, relative plant vigor (size, color, and transition from winter to spring growth), aboveground dry weight (biomass), persistence, and plant habit and coloration with commercial rangeland cultivar controls Nezpur (4x; *F. idahoensis* L.), Joseph (4x; *F. idahoensis*), Bighorn (2x; *F. ovina*), Covar [2x; *F. valesiaca* Schleich. ex Gaudin subsp. *valesiaca* (Volga fescue)], and Durar [6x; *F. trachyphylla* (Hack.) Krajina (hard fescue)] in replicated trials. These *Festuca* controls were chosen because of their taxonomic relationships to plants of FEID 9025897 (Jones et al., 2008; Staub et al., 2014) and their adaptation to and widespread use on western U.S. semiarid rangelands. To compare experimental material to available and taxonomically appropriate material in the USDA-ARS Germplasm Resources Information Network (GRIN; <http://www.ars-grin.gov/>), five U.S. native PI accessions (*F. idahoensis*; PIs 344597, 344604, 344609, 344614, and 344631) were also evaluated. In addition, three ornamental grasses, Red Spire [*Melica transsilvanica* Schur., abbreviated MeTr; obtained from Seedman.com (Gulf Coast, MS)], Florist

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switchgrass (synom. tall switchgrass) (*Panicum virgatum* L., ‘Strictum’; abbreviated PaVi; obtained from Seedman.com), and Chinese fountaingrass [*Pennisetum alopecuroides* (L.) Spreng; abbreviated PeAl; obtained from Outsidepride.com (Salem, OR)] were included as horticultural controls because they exhibit panicle coloration at maturity. Of the 19 selections, ARS FEID-2, ARS FEID-64, and ARS FEID-98 did not produce enough clones and were eliminated from the evaluation.

Cloned plants and seedlings of the checks were evaluated in a randomized complete block design with four replications of five plants per plot for 2 years (2014–15) in field nurseries at the Utah State University Greenville Research farm in Logan (41°45′56.01″N lat., 111°48′39.69″W long.; 1407 m elevation, average July temperature and annual 20-year precipitation = 31.7 °C and 437 mm, respectively, Millville silt loam, pH ≈7.9, EC ≈1.0 dS·m⁻¹, 2% organic matter), Kaysville (41°1′17.36″N lat., 111°56′17.95″W long.; 1340 m elevation, average July temperature and average annual 20-year precipitation = 33.3 °C and 488 mm, respectively, Parley’s loam, pH ≈7.4, ≈7.4 dS·m⁻¹, and 4% organic matter), and Vernon (40°19′18″N lat., 112°26′12.20″W long.; 1697 m elevation, average July temperature and 20-year annual precipitation = 32.2 °C and 287 mm, respectively, Taylorsflat loam, pH ≈9.1, ≈1.0 dS·m⁻¹, and 1.5% organic matter), Utah. Plants were spaced 0.5 m within the rows and 1 m between rows (≈20,000 plants/ha) with Durar or ‘Covar’ used as end- and side-borders.

To evaluate plant materials under low-input irrigation, water was applied by overhead sprinklers to field capacity only when the average soil moisture tension was less than 3.5 bars, as measured by a Delmhorst KS-D1 moisture tester and 12 gypsum soil blocks (Dolmhorst Instrument Co., Towaco, NJ) randomly placed throughout the trial at a soil depth of 9 inches. This resulted in an average irrigation frequency of once every 3 weeks in Vernon, UT, and once every month in Logan and Kaysville, UT, during the summer (June, July, and August) months. No supplemental fertilizer was applied to plants at planting, during establishment, or at any point during the experiment. Plots were hand-weeded each year from May to August and broadleaf weeds were also controlled with herbicide [mixture of 2,4-D (30.56%), mecoprop-p (8.17%), and dicamba (2.77%); MEC Amine-D; Loveland Products, Greeley, CO; U.S. Environmental Protection Agency (EPA) registration no. 34704-239] application once in April or May of each year at a rate of 3.0 (2,4-D), 0.8 (mecoprop-p), and 0.3 (dicamba) g·ha⁻¹ a.i.

During the first 2 weeks of May of each year (2014 and 2015), the relative plant vigor of all entries was assessed using a 11-point visual rating scale from 0 to 5 (0.5 as units), where plant vigor (size, color, and transition from winter to spring growth) was defined as 0 = plant dead, 2.5 = plants possessing

moderate biomass or leaf blade length with green (light to dark) foliage (tussock evident), and 5 = green plants having comparatively abundant aboveground biomass and/or long leaf blade length. During the last 2 weeks of June of each year, the height (centimeters) of each plant was measured as the distance from the plant base (soil surface) to the top of the highest floret at full anthesis (florets were gathered and straightened upward for measurement). Leaves and inflorescence spikes were harvested ≈10 cm aboveground when inflorescences were dry, then oven-dried at 60 °C to estimate plant biomass as total aboveground dry weight (grams/plant). After aboveground harvesting, plant width was measured as the diameter of the remaining leaves and stems. Persistence and flowering percentage was determined by counting the number of plants alive and with at least one inflorescence, respectively, within each plot at the time of harvest.

Color of the tussock (base), culm, and panicle were obtained through visual evaluation as assessed once at each location by 4–8 judges in late June or early July when optimal coloration was observed among cloned plants, which was location and year dependent. Judges examined and characterized coloration separately for four areas (hereafter referred to as rating areas) of the plant: 1) the

base (tussock), 2) lower third, 3) middle third, and 4) top third of inflorescences of all plants within a plot. To avoid intense sunlight and standardize for daytime light levels, all ratings were taken for all entries in a trial on a single, clear day between 0800 and 1100 HR. Trials were rated separately on different days and, where possible, with the same judges. Logistically, however, it was not possible for all judges to rate all three trials. Colors assigned by judges were based on approximate alignments with Royal Horticulture Society (RHS) color chart designations (edition V; rhs.org.uk). Judges identified green (RHS 140A), blue-green (RHS 125A), gray (RHS N187D), brown (RHS 165A), yellow (RHS 4A), gold (RHS 7C), orange (RHS N25C), pink (RHS 67D), salmon (RHS 58C), maroon (RHS N79C), and purple (RHS N78A).

The average percentage color distribution (APCD) for each rating area was calculated over replications and judges for each entry as the sum of the ratings for that color divided by the total number of ratings multiplied by 100 [e.g., % green at the base = (green base ratings/total base ratings)*100]. In addition, judges assigned an overall color intensity rating of 1–5 (0.5 units; 1 = no color, 3 = moderate color intensity, and 5 = vibrant color intensity) to entries by plot (one value

Fig. 1. Average percentage color distribution (APCD) according to Royal Horticulture Society color chart designation (under color name) of four selected *Festuca* ornamental grasses, ‘Francy’ (ARS FEID-33), ‘Vida’ (ARS FEID-23), ‘Heidi’ (ARS FEID-251), and ‘Kim’ (ARS FEID-258) in 2014. Profiles include four rating areas of the plant including the base (tussock), and the bottom third, middle third, and top third of the inflorescence (culm and panicle). Numbers indicate average percentage of each color in each rating area over three locations (Logan, Kaysville, and Vernon, UT) by 3–5 judges per location.

per plot), which was then averaged over replications to provide an average relative color intensity (ARC) for each entry. Judges also assigned a plant habit rating for each plot on a scale of 1–3 (0.5 units), where inflorescences were 1 = upright (inflorescences between 0° and 30° from vertical), 2 = pendulant (30–60° from vertical), and 3 = approaching prostrate (60–90° from vertical). These ratings were also averaged over replications and judges for each entry. The APCD, ARC, and habit displayed for each entry at each rating area were compared with *Festuca* controls. Those entries that exhibited the most diversity of color (overall APCD) with the most intense hues (ARC) and a more upright habit were considered for release. Except for APCD, morphological and ARC data were analyzed on per-plot means in analysis of variance (ANOVA) using a linear mixed models analysis under which residuals for all traits were tested for normality using PROC UNIVARIATE in SAS software (Version 9.3 for Windows; SAS Institute, Cary, NC). The APCDs taken over locations for specific clones are presented according to RHS color chart designations by year.

Description

Significant ($P < 0.001$) differences among the clones and commercial checks were detected for all morphological traits measured, which were year and location dependent. Nevertheless, the mean differences among cultivars for all traits were, with rare exception, ones of magnitude and not rank order over years and locations.

Differences in culm and panicle coloration (APCD and ARC) were detected among the plants examined depending on evaluation year and location (Figs. 1 and 2; Tables 1 and 2). However, with rare exception, location color differences for entries were ones of magnitude (APCD for each color) and not rank (change in relative hierarchy). Thus, color counts were averaged over replications and locations to estimate the APCD of every rating area of each entry in each year. Differences in average ARC detected among entries over locations were also of magnitude (relative color intensity) and not rank (change in relative hierarchy). Hence, entry ARC values were also averaged over replications and locations to provide ARC values for each entry by year (Tables 1 and 2).

For those entries exhibiting panicle and culm coloration, purple, maroon, pink, salmon, yellow, and gold culm and panicle coloration were more frequent (APCD) and intense (ARC) at Logan and Kaysville than in Vernon regardless of the year (data not presented). Culms and panicles of plants evaluated in 2014 possessed comparatively more gold, yellow, and pink coloration than in 2015, which was marked by a general preponderance of maroon coloration along with lower percentages of pink and salmon

depending on the clone examined (data not presented).

Mean trait values of vigor, biomass, percent flowering, height, and width were higher in 2015 than 2014, though not always statistically significant. For instance, overall trait values of persistence, habit, and ARC were not significantly different between the 2 years (Tables 1 and 2; Figs. 1 and 2). The overall mean of ARC of all plants examined was similar between 2014 (2.9) and 2015 (2.9), and ranged from 1.0 to 4.3 and 1.3 to 4.2, respectively (Tables 1 and 2). Taken collectively, the ARC of plants at Kaysville (3.1) were greater than that of Vernon (2.8; $P < 0.05$), whereas that of Logan (2.9) was not significantly different from the other locations. The ARC of control cultivars ranged from 1.0 (MeTr, PaVi, and PeAl) to 3.1 (Bighorn and Covar) and from 1.3 (MeTr) to 3.1 (Covar and Durar) in 2014 and 2015, respectively. Experimentals ARS FEID-33, ARS FEID-23, ARS FEID-251, and ARS FEID-258 received the highest ARC among clones and controls (average ARC over both years = 3.9; max ARC = 4.3) over years and locations, and were designated “Francy” (average ARC = 4.3), “Vida” (average ARC = 3.8), “Heidi” (average ARC = 3.8), and “Kim” (average ARC = 3.7), respectively (Tables 1 and 2).

Tussock coloration consisted of green, blue-green, gold, salmon, and brown in these clones (‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’) and commercial cultivars depending on growing environment. Tussock coloration of ‘Francy’ was predominantly green (80% to 88%) with lesser contributions of blue-green (0% to 13%), whereas that of ‘Vida’, ‘Heidi’, and ‘Kim’ was green (44% to 65%) with contributions of blue-green (27% to 53%) coloration depending on year and growing location (Figs. 1 and 2). The extent of brown and gray coloration apparent in ‘Francy’ (8% and 0%, respectively), ‘Vida’ (12% and 0%, respectively), ‘Heidi’ (4% and 0%, respectively) and ‘Kim’ (4% and 0%, respectively) (Figs. 1 and 2) often differed from that in commercial controls (4% and 0.03%, respectively; data not presented).

Culm and panicle coloration of ‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’ most frequently included various quantities (APCD) and intensities (ARC) of brown, gold, yellow, orange, pink, salmon, maroon, and purple depending on growing environment and year. Culms and panicles of ‘Francy’ exhibited a broad array of intense orange (0% to 15%), yellow (1% to 8%), gold (5% to 11%), pink (10% to 20%), purple (0% to 20%), salmon (1% to 13%), and maroon (24% to 36%) coloration (Figs. 1–3). Those

Fig. 2. Average percentage color distribution (APCD) according to Royal Horticulture Society color chart designation (under color name) of four selected *Festuca* ornamental grasses, ‘Francy’ (ARS FEID-33), ‘Vida’ (ARS FEID-23), ‘Heidi’ (ARS FEID-251), and ‘Kim’ (ARS FEID-258) in 2015. Profiles include four rating areas of the plant including the base (tussock), and the bottom third, middle third, and top third of the inflorescence (culm and panicle). Numbers indicate average percentage of each color in each rating area over three locations (Logan, Kaysville, and Vernon, UT) by 3–5 judges per location.

Table 1. Mean morphological trait values of *Festuca* ornamental grass entries (ARS FEID prefix) and checks over three locations (Logan, Kaysville, and Vernon, UT) in 2014.

Entry	Vigor ^z (rate 0–5)	Biomass ^z (g)	Persistence ^z (%)	Flowering ^z (%)	Ht ^z (cm)	Width ^z (cm)	Habit ^z (rate 1–3)	ARC ^z (rate 0–5)
ARS FEID-23 (‘Vida’)	2.8	60.93	100.0	100.0	74.1	22.4	1.6	3.6
ARS FEID-26	2.3	40.26	95.0	100.0	70.1	20.2	1.4	3.3
ARS FEID-30	2.2	42.54	88.3	100.0	58.0	20.1	1.5	3.4
ARS FEID-33 (‘Francy’)	3.1	72.87	96.7	100.0	78.5	22.4	1.4	4.3
ARS FEID-44	2.4	31.78	96.7	100.0	67.3	16.3	1.8	2.9
ARS FEID-66	1.8	17.93	95.0	95.0	60.8	15.1	1.8	3.1
ARS FEID-79	2.2	34.03	96.7	96.7	66.4	20.2	1.9	3.0
ARS FEID-83	2.0	23.89	96.7	100.0	54.1	19.9	1.9	3.2
ARS FEID-89	2.1	16.13	90.0	91.7	34.8	15.9	2.4	2.9
ARS FEID-90	2.0	21.28	95.0	100.0	59.5	16.8	2.1	3.1
ARS FEID-113	2.3	24.89	98.3	100.0	52.6	20.1	1.6	3.1
ARS FEID-130	2.7	36.60	98.3	100.0	60.5	23.5	2.1	3.2
ARS FEID-222	2.2	21.33	96.7	96.7	62.5	19.2	2.0	3.4
ARS FEID-251 (‘Heidi’)	2.3	46.57	100.0	100.0	76.7	19.4	1.5	4.1
ARS FEID-258 (‘Kim’)	2.5	37.52	100.0	100.0	68.2	19.7	1.2	3.4
ARS FEID-261	2.1	32.04	100.0	100.0	63.7	18.4	1.5	3.3
Bighorn	3.0	24.78	98.3	100.0	51.1	21.6	2.3	3.1
Covar	2.9	39.11	91.7	98.3	68.4	18.3	1.7	3.1
Durar	3.2	48.13	100.0	100.0	70.2	18.9	1.7	2.9
Joseph	1.7	13.17	70.0	80.0	47.5	17.6	2.6	2.8
Nezpurs	1.6	12.69	78.3	76.7	58.9	14.7	2.0	2.9
PI 344597	1.7	28.99	80.0	87.9	63.8	13.5	1.8	2.9
PI 344604	1.3	8.22	46.7	76.7	50.4	12.4	1.8	2.8
PI 344609	1.8	18.29	90.0	95.0	51.6	15.0	1.6	3.0
PI 344614	1.6	13.54	60.0	93.3	58.3	12.6	1.8	2.8
PI 344631	1.8	17.07	76.7	90.0	58.0	15.1	1.9	2.7
MeTr ^y	3.0	34.74	93.3	78.3	83.2	20.2	1.6	1.0
PaVi ^y	1.2	10.46	85.0	33.3	44.3	11.7	2.1	1.0
PeAl ^y	1.6	94.29	86.7	52.8	38.1	32.2	2.9	1.0
Mean	2.2	31.86	89.7	91.1	60.4	18.4	1.8	2.9
LSD($\alpha = 0.05$) ^x	0.3	10.17	13.3	8.4	6.7	3.0	0.2	0.3
CV (%) ^w	40.8	55.90	18.5	16.0	19.4	28.4	21.5	21.0

^zTrait values are vigor = rating (0.5 scale) from 0 = dead to 5 = most vigorous; biomass = aboveground dry weight (grams/plant); persistence = percentage of plants alive at biomass harvest; flowering = percentage of plant with at least one inflorescence at biomass harvest; height = distance from soil to highest inflorescence at anthesis; habit = rating (0.5 scale) from 1 = upright to 3 = approaching prostrate; ARC (average relative color) = color intensity rating (0.5 scale) from 1 = no color to 5 = vibrant color intensity.

^yHorticultural checks are MeTr (*Melica transsilvanica* Schur., ‘Red Spire’), PaVi [*Panicum virgatum* L., ‘Strictum’; florist switchgrass (synom. tall switchgrass)], and PeAl [*Pennisetum alopecuroides* (L.) Spreng; Chinese fountaingrass].

^xLeast significant difference.

^wCoefficient of variation.

of ‘Vida’ displayed orange, (0% to 10%), yellow (1% to 9%), gold (1% to 38%), pink (7% to 36%), purple (3% to 10%), salmon (3% to 17%), and maroon (2% to 31%) coloration. Although culms and panicles of ‘Heidi’ showed orange (3% to 7%), yellow (3% to 19%), gold (7% to 32%), pink (14% to 31%), purple (0% to 3%), salmon (2% to 18%), and maroon (15% to 54%) color patterns, those of ‘Kim’ demonstrated orange (0% to 15%), yellow (0% to 13%), gold (2% to 15%), pink (8% to 33%), purple (0% to 4%), salmon (2% to 16%), and maroon (6% to 38%) pigmentation. These values differ appreciably from commercial controls for orange (0% to 1%), yellow (7% to 38%), gold (10% to 32%), pink (0% to 19%), purple (0% to 2%), salmon (8% to 68%), and maroon (0% to 10%) coloration (data not presented).

The average relative plant vigor of the germplasm evaluated was greater in 2015 (2.6) than 2014 (2.2), where average vigor rating in 2014 and 2015 ranged from 1.2 to 3.2 and 1.9 to 3.2, respectively (Tables 1 and 2). The average vigor of plants grown in

Kaysville (2.6) was greater than Logan (2.3) and Vernon (2.2), which were not significantly different. The mean vigor of checks ranged from 1.2 (PaVi) to 3.2 (Durar) and from 1.9 (PaVi) to 3.1 (Durar) in 2014 and 2015, respectively. The average vigor of ‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’ was 3.2, 3.0, 2.5, and 2.7, respectively.

The average aboveground dry weight (biomass) of all plants examined was higher in 2015 (38.28 g) than 2014 (31.86 g), where average weight in 2014 and 2015 ranged from 8.22 to 94.29 (PeAl) g and 14.35 to 110.71 g, respectively (Tables 1 and 2). The average dry weight of plants grown in Kaysville (40.10 g) and Logan (36.45 g) were higher than Vernon (28.67 g). The mean dry weight of checks ranged from 8.22 (PI 344604) to 94.29 (PeAl) g and from 14.60 (PI 344614) to 71.90 (PeAl) g in 2014 and 2015, respectively. The average biomass of ‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’ was 68.88, 85.82, 35.99, and 48.74 g, respectively.

The average persistence of all entries was similar in 2014 (89.7%) and 2015

(88.3%), where the average persistence ranged from 46.7% to 100% and 51.7% to 100% in 2014 and 2015, respectively (Tables 1 and 2). The average persistence of plants grown in Vernon (92.1%) and Kaysville (90.6%) were similar and greater than in Logan (84.3%). The mean persistence of checks ranged from 60% (PI 344614) to 100% (Durar) and from 57.5% (PI 344614) to 98.3% (Durar and Bighorn) in 2014 and 2015, respectively. The average persistence of ‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’ was 97.5%, 100%, 100%, and 100% respectively.

The average percentage of plants that produced inflorescences (flowering) was greater in 2015 (98.8%) than in 2014 (91.1%) and ranged from 33.3% to 100% in 2014 and 88.3% to 100% in 2015. Flowering was similar in Logan (98.9%) and Vernon (97.0%), which were greater than in Kaysville (89.1%). The mean percent flowering of checks ranged from 33.3% (PaVi) to 100% (Bighorn and Durar) and 88.3% (MeTr) to 100% (several checks) in 2014 and 2015, respectively. The average percent flowering

Table 2. Mean morphological trait values of *Festuca* ornamental grass entries (ARS FEID prefix) and checks over three locations (Logan, Kaysville, and Vernon, UT) in 2015.

Entry	Vigor ^z (rate 0–5)	Biomass ^z (g)	Persistence ^z (%)	Flowering ^z (%)	Ht ^z (cm)	Width ^z (cm)	Habit ^z (rate 1–3)	ARC ^z (rate 0–5)
ARS FEID-23 (‘Vida’)	3.1	110.71	100.0	100.0	89.0	30.6	1.6	4.0
ARS FEID-26	2.9	54.53	93.3	100.0	74.5	23.9	1.5	3.2
ARS FEID-30	2.7	42.62	88.3	100.0	61.8	23.4	1.4	3.0
ARS FEID-33 (‘Francy’)	3.2	64.89	98.3	100.0	82.8	27.7	1.4	4.2
ARS FEID-44	2.6	33.28	96.7	100.0	69.3	21.0	1.6	3.1
ARS FEID-66	2.3	27.25	88.3	100.0	68.4	18.5	1.4	3.2
ARS FEID-79	2.5	27.79	93.3	96.3	59.9	23.0	1.9	2.9
ARS FEID-83	2.5	27.33	93.3	100.0	57.8	22.1	1.4	3.3
ARS FEID-89	2.4	14.35	96.7	100.0	34.1	20.7	2.6	2.5
ARS FEID-90	2.3	18.27	96.7	100.0	63.1	21.1	1.5	2.7
ARS FEID-113	2.8	28.37	98.3	100.0	56.3	25.4	1.6	3.2
ARS FEID-130	3.0	61.54	98.3	100.0	71.3	27.6	1.8	3.2
ARS FEID-222	2.4	21.53	96.7	100.0	63.7	21.9	1.8	3.1
ARS FEID-251 (‘Heidi’)	2.7	25.40	100.0	100.0	76.1	24.3	1.5	3.5
ARS FEID-258 (‘Kim’)	2.9	59.96	100.0	100.0	82.0	25.9	1.1	3.9
ARS FEID-261	2.5	41.68	100.0	100.0	70.8	24.4	1.6	3.2
Bighorn	2.8	36.46	98.3	100.0	62.7	28.2	2.3	2.9
Covar	2.8	44.09	88.3	100.0	74.5	24.1	1.9	3.1
Durar	3.1	59.11	98.3	100.0	74.8	24.4	2.1	3.1
Joseph	2.4	16.37	73.3	93.9	47.5	20.8	2.3	2.4
Nezpurs	2.2	16.25	70.0	99.4	64.4	19.7	2.0	2.8
PI 344597	2.3	38.81	78.3	100.0	73.9	18.5	1.7	2.8
PI 344604	2.1	25.01	51.7	99.8	61.8	19.4	1.9	2.5
PI 344609	2.5	25.20	93.3	100.0	55.3	19.7	1.7	3.1
PI 344614	2.2	14.60	57.5	95.8	64.9	17.6	1.6	2.6
PI 344631	2.3	24.45	78.3	100.0	58.9	17.5	1.7	2.4
MeTr ^y	2.4	45.68	85.5	88.3	92.8	24.7	1.7	1.3
PaVi ^y	1.9	32.75	68.3	100.0	80.7	19.2	2.0	1.7
PeAl ^y	2.9	71.90	81.7	93.0	55.0	31.9	2.9	1.4
Mean	2.6	38.28	88.3	98.8	67.2	23.0	1.8	2.9
LSD _(α = 0.05) ^x	0.3	10.17	13.3	8.4	6.7	3.0	0.2	0.4
CV (%) ^w	34.6	46.53	18.8	14.7	17.4	22.7	24.6	25.9

^zTrait values are vigor = rating (0.5 scale) from 0 = dead to 5 = most vigorous; biomass = aboveground dry weight (grams/plant); persistence = percentage of plants alive at biomass harvest; flowering = percentage of plant with at least one inflorescence at biomass harvest; height = distance from soil to highest inflorescence at anthesis; habit = rating (0.5 scale) from 1 = upright to 3 = approaching prostrate; ARC (average relative color) = color intensity rating (0.5 scale) from 1 = no color to 5 = vibrant color intensity.

^yHorticultural checks are MeTr (*Melica transsilvanica* Schur., ‘Red Spire’), PaVi [*Panicum virgatum* L., ‘Strictum’; florist switchgrass (synom. tall switchgrass)], and PeAl [*Pennisetum alopecuroides* (L.) Spreng; Chinese fountaingrass].

^xLeast significant difference.

^wCoefficient of variation.

of ‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’ was 100%.

Average height of all plants examined was higher in 2015 (67.2 cm) than in 2014 (60.4 cm), where average height in 2014 and 2015 ranged from 34.8 to 83.2 cm and 34.1 to 92.8 cm, respectively (Tables 1 and 2). The average height of plants grown in Logan (72.1 cm) was higher than Vernon (60.5 cm) and Kaysville (58.8 cm), which were not significantly different. The average heights of checks ranged from 44.3 (PaVi) to 83.2 (MeTr) cm and from 47.5 (Joseph) to 92.8 (MeTr) cm in 2014 and 2015, respectively. The average height of ‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’ was 80.7, 81.6, 76.4, and 75.1 cm.

The average width of all plants examined was higher in 2015 (23.0 cm) than in 2014 (18.4 cm), where average width in 2014 and 2015 ranged from 11.7 to 32.2 cm and 17.5 to 31.9 cm, respectively (Tables 1 and 2). The average width of plants grown in Logan (21.8 cm) was higher than Kaysville (20.2 cm) and Vernon (20.1 cm), which were not significantly different. The average width of checks

ranged from 11.7 (PaVi) to 32.2 (PeAl) cm and from 17.5 (PI 344631) to 31.9 (PeAl) cm in 2014 and 2015, respectively. The average width of ‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’ was 25.1, 26.5, 21.9, and 22.8 cm, respectively.

For plant habit, where the rating scale is based on 1 for upright and 3 for almost prostrate, a lower value represents a more upright, horticulturally desirable plant. The average rating for plant habit for all entries was no different between 2014 (1.8) and 2015 (1.8) and ranged from 1.2 to 2.9 in 2014 and 1.1 to 2.9 in 2015 for all material evaluated. Plants were more upright in Vernon (1.6) than in Kaysville or Logan, where the average rating for each location was 1.9. The average habit rating for checks was from 1.6 (MeTr and PI 344609) to 2.9 (PeAl) in 2014 and from 1.6 (PI 344614) to 2.9 (PeAl) in 2015. The average habit rating of ‘Francy’, ‘Vida’, ‘Heidi’, and ‘Kim’ was 1.4, 1.6, 1.5, and 1.2, respectively.

Sterile, tall-statured, erect ‘Francy’ [patent pending (PP) U.S. Plant Patent Application Serial No. (No.) 15/530,172], ‘Vida’ (PP

No. 15/530,183), ‘Heidi’ (PP No. 15/530,171), and ‘Kim’ (PP No. 15/530,184) are naturally occurring hybrid fescue grasses that differ in their morphological attributes and are being released by the FRRL as a *Festuca* group designated as the “Freedom Fire Series” for horticultural applications because of their exceptional culm and panicle coloration in late June and early July (typically 3–4 weeks) under northern Utah growing environments (Fig. 3). All four grasses persist well, almost always produce inflorescences, and are generally more vigorous than the other entries and commercial controls under the conditions examined. However, ‘Francy’ and ‘Vida’ are larger and more vigorous than ‘Heidi’ and ‘Kim’. Although vegetative propagation rates were not formally measured, production observations indicate that although there are differences in relative propagation ability, the four selections propagate to commercial standards (‘Francy’ = ‘Vida’ > ‘Kim’ > ‘Heidi’; D. Heslop, personal communication, Biogress Sod Farms, 2016). Vegetative propagation success was lower between November and

Fig. 3. Coloration of four selected *Festuca* ornamental grasses as they appeared in Logan, UT, in July 2016. Panels are (A) 'Francy' (ARS FEID-33), (B) 'Vida' (ARS FEID-23), (C) 'Heidi' (ARS FEID-251), and (D) 'Kim' (ARS FEID-258).

late February (i.e., short-days and reduced natural light). Even though all are relatively tall and erect, 'Kim' is more upright than the others. Although these germplasms vary in their tussock, clum, and panicle coloration depending on growing environment, their coloration is substantially more intense (higher ARC) with a wider range of colors (APCD) than the *Festuca* commercial controls examined herein. They are suggested for use in low-input urban garden settings as a backdrop for lower statured plant materials and/or as accents in formal gardens where coloration is desired in early summer (end of June, beginning of July). Their coloration and

growth is optimized when grown in full light and where water is limited.

Availability

Samples of cloned plants are available for distribution to all interested parties for research purposes, through the USDA, ARS. Requests of clonal propagules for such purposes should be sent to Dr. Matthew D. Robbins, USDA, Forage and Range Research Laboratory, 700 N. 1100 E. Logan, UT 84322; e-mail matthew.robbins@ars.usda.gov. For commercial and private use, clonal plant material can be obtained from Biograss

Sod Farms, 9980 S. State Street, Sandy, UT; Biograss.com after plant patent has been awarded.

Literature Cited

- Aronson, L.J., A.J. Gold, and R.J. Hull. 1987. Cool-season turfgrass responses to drought stress. *Crop Sci.* 27:1261-1266.
- Barkworth, M.E., K.M. Capels, S. Long, L.K. Anderton, and M.B. Piep (eds.). 2007. *Flora of North America*. Oxford University Press, New York, NY.
- Beard, J.B. and R.L. Green. 1994. The role of turfgrasses in environmental protection and their benefits to humans. *J. Environ. Qual.* 23:452-460.

- Cook, T. 1996. Low maintenance turf. Oregon State University, Corvallis, OR.
- Damschen, E.I., N.M. Haddad, J.L. Orrock, J.J. Twilley, and D.J. Levey. 2006. Corridors increase plant species richness at large scales. *Science* 313(5791):1284–1286.
- Dewey, D.W., P.G. Johnson, and R.K. Kjelson. 2006. Effects of irrigation and mowing on species diversity of grass and wildflower mixtures for the Intermountain West. *Native Plants J.* 7:267–278.
- Fender, D. 2006. Urban perennial grasses in time of water crisis: Benefits and concerns. Council for agricultural science and technology (CAST). Water quality and quantity issues for turfgrasses in urban landscapes, Las Vegas, NV.
- Jones, T.A., S.R. Larson, and B.L. Wilson. 2008. Genetic differentiation and admixture among *Festuca idahoensis*, *F. roemerii*, and *F. ovina* detected in AFLP, ITS, and chloroplast DNA. *Botany* 86:422–434.
- Lohr, V.I., C.H. Pearson-Mims, and G.K. Goodwin. 2007. Interior plants may improve worker productivity and reduce stress in a windowless environment. *Plants in buildings*. 8 Aug. 2013. <<http://www.plants-in-buildings.com/whyplantsstressreduction.php>>.
- Loram, A., P.H. Warren, and K.J. Gaston. 2008. Urban domestic gardens (XIV): The characteristics of gardens in five cities. *Environ. Mgt.* 42:361–376.
- Ruemmele, B.A., J.K. Wipff, L. Brilman, and K.W. Hignight. 2003. Fine-leaved *Festuca* species, p. 129–172. In: M.D. Casler and R.R. Duncan (eds.). *Turfgrass biology, genetics, and breeding*. John Wiley and Sons, Hoboken, NJ.
- Staub, J.E., M.D. Robbins, Y. Ma, and P.G. Johnson. 2014. Phenotypic and genotypic analysis of a U.S. native fine-leaved *Festuca* population reveals its potential use for low-input urban landscapes. *J. Amer. Soc. Hort. Sci.* 139:706–715.
- Thetford, M., J.G. Norcini, B. Ballard, and J.H. Aldrich. 2009. Ornamental landscape performance of native and nonnative grasses under low-input conditions. *HortTechnology* 19:267–285.
- Wilson, C.R. 2011. Ornamental grasses. Extension bulletin no. 7.232. Colorado State University, Fort Collins, CO. 11 Aug. 2013. <www.ext.colostate.edu/pubs/garden/07232.html>.
- Wilson, S.B. and G.W. Knox. 2006. Landscape performance, flowering, and seed viability of 15 Japanese silver grass cultivars grown in northern and southern Florida. *HortTechnology* 16:686–693.
- Worldwatch Institute. 2007. Cities key to tackling poverty and climate change. 15 Aug. 2016. <<http://worldwatch.org/node/4839>>.
- Wolf, K.L. 2004. Trees, parking and green law: Strategies for sustainability. University of Washington. 10 Aug. 2016. <www.cfr.washington.edu/research.envmind/Roadside/Trees_Parking.pdf>.