

Registration of 'KSUZ 0802' Zoysiagrass

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Abstract

KSUZ 0802 (Reg. No. CV-282, PI 678793) is a fine-textured, cold-tolerant zoysiagrass (*Zoysia* spp.) hybrid co-developed and jointly released by Texas A&M AgriLife Research, Dallas, TX, and the Kansas Agricultural Experiment Station, Manhattan, KS. KSUZ 0802 is an F₁ interspecific hybrid developed in 2001 from a cross between *Zoysia matrella* (L.) Merr. 'Cavalier' and an ecotype of *Z. japonica* Steud. named Anderson 1, a derivative of 'Chinese Common'. After years of testing (2004–2008) for turf quality and winter survival at Manhattan, KS, KSUZ 0802 was advanced to a nine location test (2009–2012) in the transition zone (Wichita and Manhattan, KS, Columbia, MO, Fletcher and Jackson Springs, NC, Stillwater, OK, Knoxville, TN, Virginia Beach and Blacksburg, VA, and Dallas, TX. The freezing tolerance, spring green-up, and fall color retention of KSUZ 0802 is equivalent to 'Meyer', but KSUZ 0802 has a finer leaf texture. KSUZ 0802 is also superior to Meyer for turf quality and resistance to bluegrass billbug damage. KSUZ 0802 is well suited for use on golf course fairways and tees, home lawns, and other recreational areas in the transition zone.

ZOYSIAGRASS (*Zoysia* spp.) is one of the most versatile warm-season turfgrasses used on lawns, landscapes, and golf courses. The *Zoysia* genus displays a wide range of genetic variability (Brede and Sun, 1995) and includes 11 different species (Anderson, 2000), of which *Zoysia japonica* Steud. (Japanese lawngrass), *Z. matrella* (L.) Merr. (Manila grass), and *Z. pacifica* (Goudsw.) M. Horts and S. Kuroki (Mascarenagrass) are recognized in the United States as turfgrass species. Generally, *Zoysia* spp. possess good tolerance to heat, shade, and salt and require minimal nutrition and mowing (Christians and Engelke, 1994; Qian and Engelke, 2000; Qian et al., 2000; Baldwin et al., 2009; Patton, 2009; Wherley et al., 2011). Some cultivars, particularly within *Z. japonica*, have good freezing tolerance (Fry and Huang, 2004; Patton and Reicher, 2007; Hinton et al., 2012). Although a diploid *Z. matrella* accession ($2n = 2x = 20$) has been reported (Gould and Soderstrom, 1974), most zoysiagrasses are tetraploid with $2n = 4x = 40$ (Forbes, 1952; Arumuganathan et al., 1999). Species of *Zoysia* are cross-compatible, making interspecific hybridization feasible.

The *Zoysia* genus is indigenous to the Pacific Rim countries, with geographic distribution extending from 42° N to 42° S (Anderson, 2000). In the United States, zoysiagrass is best adapted to and widely used in the southern and southeastern regions. Freezing tolerance is the most important factor limiting its widespread use in the transition zone, the center of which runs from eastern New Mexico to northern Virginia (Fry and Huang, 2004). *Zoysia japonica* 'Meyer' (Grau and Radko, 1951) has been the predominant cultivar used in the transition

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Abbreviations: LT₅₀, lethal temperature resulting in death of 50% of grass tillers; TPI, turfgrass performance index.

zone since 1952 because of its excellent freezing tolerance. A recently released *Z. japonica* cultivar, 'Chisholm' (Chandra et al., 2015), has freezing tolerance that is comparable or slightly poorer than Meyer, but with a superior rate of establishment, turf quality, growth under shade, and tolerance to pests compared with Meyer. Both Meyer and Chisholm exhibit medium-coarse to coarse leaf texture suitable for lawns and golf course fairways. *Zoysia matrella* cultivars such as 'Cavalier' (Engelke et al., 2002a) 'Diamond' (Engelke et al., 2002b), 'Zeon' (Doguet, 2002), 'Royal' (Engelke and Reinert, 2003b), and 'Zorro' (Engelke and Reinert, 2003a) exhibit finer leaf texture but have poor to moderate freezing tolerance with limited adaptation into the transition zone. The objective of this breeding effort was to develop an interspecific hybrid between *Z. matrella* and *Z. japonica* with finer leaf texture and better quality than Meyer but freezing tolerance comparable or superior to Meyer.

Methods

Development of Interspecific Hybrids

KSUZ 0802 (Reg. No. CV-282, PI 678793), formerly tested as TAES 5311-26, was one of 60 individuals derived from crosses between *Z. matrella* cultivar Cavalier and *Z. japonica* ecotype Anderson 1. Anderson 1, a derivative of 'Chinese Common', was one of two ecotypes collected from Alvamar Golf and Country Club in Lawrence, KS; Mel Anderson is a former golf course superintendent at Alvamar who pioneered zoysiagrass use in the Midwest. Controlled hand pollinations were made in 2001 at Texas A&M AgriLife Research–Dallas by pollinating the receptive protogynous flower with pollen collected from the male parent in a glycine shoot bag. Identity of pollinated flowers was maintained by placing a bamboo skewer next to the pollinated inflorescences and covering with an Eppendorf tube (VWR). Flowers were allowed to mature for 6 wk before seed was harvested. Dried seeds were processed by dissecting hulls away from the caryopsis using a dissecting microscope. In vitro seed germination was accomplished by surface sterilizing naked caryopses in a 50% solution of bleach (The Clorox Co.) followed by three washes with sterile deionized water. The hard seed coat of zoysiagrass required that each seed be scarified with a scalpel blade to accelerate germination on a half-strength MS medium (Caisson Laboratories). The resulting 610 progeny from 17 different families were transferred and planted in a spaced plant nursery at Kansas State University, Manhattan, KS, in 2004 and evaluated for turf quality and winter survival (Fry et al., 2008). Seven out of 610 hybrids, later coded as KSUZ 0801 to KSUZ 0807, were selected in 2008 because of their quality and freezing tolerance and were advanced for multilocation testing in the transition zone. For the purpose of this publication, we only present the comparison between KSUZ 0802 and commercial cultivars.

Morphology

KSUZ 0802 was morphologically compared to Chisholm, 'Emerald' (Forbes et al., 1955), Meyer, and Zorro. Plant material was propagated into 27.3-cm-diameter by 24.1-cm-deep pots filled with Sunshine VP mix (Sun Gro Horticulture, Inc.) and 5% sand (v/v). Three replicate pots of each genotype received fertilizer (20 N–20 P₂O₅–20 K₂O, Peter's Professional, Everris

International B.V.) monthly during establishment. Plant material was grown in a greenhouse maintained at 26/18°C day/night temperatures and 70% humidity from October 2014 through March 2015. Pots were watered, as needed, three to four times per week. In April 2015, all potted material was moved outside of the greenhouse to promote growth under natural sunlight and ambient temperature. Leaf tissue was hand-trimmed weekly during the growing season. Stolons were allowed to drape around pots. Digital calipers were used to collect data for all traits. Data were collected on 14 Jan. 2015 and 31 Mar. 2015 using plants maintained in the greenhouse, except for leaf width, which was measured on 23 June 2015 after the plants were moved outside. Color ratings were determined on noncloudy days using the Munsell Color Chart for Plant Tissues. A maximum of 12 samples from three replicate pots were measured for each trait and cultivar. Internode length and diameter were measured between the fourth and fifth nodes of the longest stolon. Stolon node diameter was measured from the fourth node. The third-youngest leaf was measured for leaf blade length and leaf width 15 mm above the collar. Flag leaf length was measured from the collar to the tip of the leaf. Inflorescence length was measured from the top of the peduncle to the tip of the raceme. Data were analyzed using the PROC GLM model in SAS 9.3 (SAS Institute, 2011). Means were separated using Fisher's protected LSD ($P \leq 0.05$).

Field Study: Multistate Progeny Evaluation

KSUZ 0802 was planted along with Meyer and Chisholm as commercial checks in summer 2009 at all locations except Manhattan, KS, where it was planted in summer 2008, and Fletcher and Jackson Springs, NC, where it was planted in summer 2010. Data from Wichita, KS (KS1), Columbia, MO, Stillwater, OK, Knoxville, TN, Dallas, TX, Virginia Beach, VA (VA1), and Blacksburg, VA (VA2) were collected from 2009 to 2012. Data from Manhattan, KS (KS2) were collected from 2008 to 2011, and data from Fletcher, NC (NC1), and Jackson Springs, NC (NC2) were collected from 2010 to 2012. The only location not in the transition zone was Dallas, TX. Experimental hybrids and checks were replicated three times in a randomized complete block design and were established vegetatively from 7.6-cm by 7.6-cm plugs. For each replication, six plugs were quartered and planted equidistant in the centermost 1.5 m by 1.5 m of 2.1-m by 2.1-m plots. Irrigation (2.5 cm) was applied to supplement rainfall each week during the first season to promote establishment and thereafter to prevent dormancy. Nitrogen was applied at 25 kg ha⁻¹ during each growing month in the first year but did not exceed a total of 100 kg ha⁻¹ in the years after establishment. Actively growing plots were mowed weekly to achieve a 3.8- to 6.4-cm cutting height recommended for home lawn management at 9 out of 10 locations. Grasses in the evaluation conducted in Manhattan were mowed 2 to 3 d per week at 1.3 cm. In Stillwater, two trials were conducted, with one mowed weekly at a 3.8 to 6.4 cm and the other mowed two or three times per week at 1.3 cm. Oxadiazon (Ronstar G, Bayer Environmental Sciences) at 146.5 kg ha⁻¹ was applied as a pre-emergence herbicide immediately after planting plugs to control summer annual weeds.

In addition to multistate progeny evaluations, results from earlier experiments have been included and summarized to

compare KSUZ 0802 with Meyer and Chisholm. Vegetative plugs of KSUZ 0802, Meyer and Chisholm planted in June 2007 and 2008 at Manhattan were evaluated for stolon growth characteristics and establishment rates (Okeyo et al., 2011a). Recovery of selected zoysiagrass progeny after sod harvest was also evaluated in Manhattan (2008 and 2009) and Olathe, KS (2009 and 2010) (Okeyo et al., 2010). Freezing tolerance of KSUZ 0802, Meyer, and Chisholm and lethal temperature resulting in death of 50% of grass tillers (LT_{50}) were determined in 2007 and 2008 at Manhattan (Okeyo et al., 2011b). In this study, grass cores measuring 6 cm in diameter were randomly collected in 2007 and 2008 from plots that were maintained at Manhattan under a cultural regimen similar to golf course fairways. The sampled cores were subjected to controlled freezing temperatures (-6 to -22°C) in a cold stress simulator during midwinter.

Multilocation Data Collection and Analysis

Establishment was rated as a percentage of plot cover from 0 to 100%, with data collected during the first growing season at all nine locations. Turf quality was rated monthly from May to September on a 1-to-9 scale considering color, density, texture, and uniformity (1 = poorest quality; 9 = optimum quality). Leaf texture was visually rated on a 1-to-9 scale (1 = very coarse, 9 = very fine). Genetic color, spring green-up, and fall color retention were rated once each year on a 1-to-9 scale (1 = brown/dead; 9 = dark green). Bluegrass billbug (*Sphenophorus parvulus* Ghyllenhal) damage was also assessed at select locations (Fry and Cloyd, 2011).

Frequency of data collection for each trait varied by location and is described in table footnotes. Data were analyzed using JMP 10 (SAS Institute, 2012) software. Analysis of variance (ANOVA) was conducted separately for each individual location using cultivar, year, and cultivar \times year interaction as fixed effects, and replications were nested within each year. If the cultivar \times year interaction was not significant for an individual location, data were pooled across years and reanalyzed. Cultivar means were separated using Fisher's protected LSD ($P \leq$

0.05). In addition, a turfgrass performance index (TPI) (Wherley et al., 2011) for each cultivar was determined by adding the number of times a cultivar appeared in the top statistical group ("a"), except for billbug damage, when cultivars in the lowest grouping were considered superior.

Characteristics

Origin

KSUZ 0802 (tested as TAES 5311-26) is an F_1 interspecific hybrid derived in 2001 from a cross between *Z. matrella* cultivar Cavalier (fine textured with poor cold hardiness) used as a female parent and *Z. japonica* ecotype Anderson 1 (cold hardy but coarse textured) used as the pollen donor. Anderson 1 was a descendant from a test plot of *Z. japonica* cultivar Chinese Common established from seed. Over an extended period of time, two ecotypes became dominant and were identified as Anderson 1 and Anderson 2. Crosses were made with both ecotypes, but Anderson 1 derivatives were generally better performing.

Morphological Description

Stolon internodes of KSUZ 0802 were longer than Chisholm, Emerald, and Meyer but similar to Zorro (Table 1). Stolon internode diameter of KSUZ 0802 was narrower than Chisholm, similar to Meyer, and wider than Emerald and Zorro, whereas stolon node diameter of KSUZ 0802 was similar to both Chisholm and Meyer but wider than Emerald and Zorro. Leaf blade lengths of KSUZ 0802 were shorter than Meyer, similar to Emerald and Zorro, and longer than Chisholm. Leaf blade widths of KSUZ 0802 were finer than Chisholm and Meyer but coarser than Emerald and Zorro. Flag leaf lengths of KSUZ 0802 were longer than Emerald and Zorro but similar to Meyer. Inflorescence lengths of KSUZ 0802 were shorter than Meyer, longer than Zorro, and similar to Chisholm and Emerald.

Table 1. Morphology of KSUZ 0802 and commercial zoysiagrass cultivars Chisholm, Emerald, Meyer, and Zorro at Dallas, TX.

| Cultivar† | Stolon‡ | | | Leaf blades§ | | Flag leaf length¶ | Inflorescence length# |
|-----------|------------------|--------------------|---------------|--------------|-------|-------------------|-----------------------|
| | Internode length | Internode diameter | Node diameter | Length | Width | | |
| | mm | | | | | | |
| KSUZ 0802 | 22.3 a†† | 1.4 b | 2.8 a | 96.5 b | 2.9 c | 8.0 a | 24.7 b |
| Chisholm | 16.4 c | 1.8 a | 2.8 a | 73.6 c | 3.7 a | – | 25.5 b |
| Emerald | 16.2 c | 1.2 c | 2.1 b | 107.0 b | 2.0 d | 3.6 bc | 22.9 b |
| Meyer | 18.2 bc | 1.5 b | 2.7 a | 169.5 a | 3.4 b | 5.6 ab | 41.0 a |
| Zorro | 21.2 ab | 1.2 c | 2.3 b | 104.5 b | 1.8 d | 1.8 c | 19.4 c |

† Cultivars were grown in a greenhouse maintained at 26°C day and 18°C night temperature and 70% humidity from Oct. 2014 through Mar. 2015 and were watered as needed three to four times per week. All replicate pots were moved outside on April 2015 to assess morphology under natural field conditions. Data were collected in 2015 on 14 Jan. 14 and 31 Mar. for all traits except leaf blade width, which was measured on 23 June.

‡ Internode length and diameter were measured from 12 samples between the fourth and fifth nodes of the longest stolons. Node diameter was measured from the fourth node.

§ Leaf blade length was measured from 12 samples on the third-youngest leaf for each cultivar; leaf blade width was measured 15 mm above the leaf collar from 12 samples on the third-youngest leaf for each cultivar.

¶ Flag leaf length was measured from the collar to the tip of the leaf. Sample number varied by cultivar but was collected from a minimum of five (KSUZ 0802) and a maximum of nine (Emerald and Zorro). Meyer was measured from eight samples. Flag leaves on Chisholm were not measured.

Inflorescence length was measured from 12 samples for each of the commercial checks and 9 samples of KSUZ 0802.

†† Means within a column followed by the same letter(s) are not significantly different at $P \leq 0.05$.

Characteristics at Lawn Height (3.8–6.4 cm)

Establishment and Recovery after Sod Harvest

KSUZ 0802 was similar to Chisholm at all nine locations and similar to Meyer at seven of the nine locations (Table 2). KSUZ 0802 had higher plot coverage compared with Meyer in Wichita, KS, and Knoxville, TN. The average across all nine locations showed that the establishment of KSUZ 0802 (74.0%) was similar to both Chisholm (76.7%) and Meyer (67.2%), but Chisholm had a greater establishment rate than Meyer, which is in agreement with Chandra et al. (2015). KSUZ 0802 and Chisholm were in the top statistical group in all nine locations, whereas Meyer was only a top performer in five of the locations.

KSUZ 0802 had greater stolon initiation rate (5.0 wk⁻¹) than Meyer (2.9 wk⁻¹) and Chisholm (2.6 wk⁻¹) in 2007 at Manhattan and had similar rates in 2008 (Okeyo et al., 2011a). KSUZ 0802, Meyer, and Chisholm had similar stolon elongation rates in 2007 and 2008. All three lines had similar stolon branching rates in 2007, but Meyer and Chisholm had higher stolon branching rates than KSUZ 0802 in 2008. As part of the same study, KSUZ 0802, planted from vegetative plugs in June 2007 and 2008 at Manhattan exhibited the same level of plot coverage in September of each year compared to Meyer and Chisholm. Generally, *Z. japonica* has been shown to display faster establishment rates and aggressive growth and regrowth characteristics compared with *Z. matrella* (Patton et al., 2007). These results show that KSUZ 0802, a finer-textured interspecific hybrid, exhibits similar stolon growth characteristics and

establishment rates when compared to Meyer and Chisholm (both *Z. japonica*).

Turf Quality

A significant ($P < 0.05$) cultivar × year effect for turf quality occurred in four locations (Wichita, KS, Stillwater, OK, Dallas, TX, and Blacksburg, VA) (Table 3). The turf quality of KSUZ 0802 was superior to Meyer in Wichita, KS (2010 and 2012), Jackson Springs, NC, Stillwater, OK (2011 and 2012), Dallas, TX (2011), and Blacksburg, VA. KSUZ 0802 was superior to Chisholm in Fletcher, NC, Stillwater, OK (2011 and 2012), and Blacksburg, VA (2012). KSUZ 0802 quality was similar to Meyer and Chisholm in Wichita, KS (2011), Columbia, MO (2010), Stillwater, OK (2010), Knoxville, TN, and Virginia Beach, VA; similar to Meyer in Fletcher, NC; and similar to Chisholm in Wichita, KS (2010 and 2012), Jackson Springs, NC, Dallas, TX (2012), and Blacksburg, VA (2010 and 2011). KSUZ 0802 was in the top statistical group in 15 of 16 analyses compared with Chisholm (TPI = 12) and Meyer (TPI = 6).

Leaf Texture

A significant ($P < 0.05$) cultivar × year effect for leaf texture occurred in Fletcher, NC, because cultivars performed differently across years (Table 4). KSUZ 0802 had a significantly finer leaf texture than both Chisholm and Meyer in six analyses (Wichita, KS, Columbia, MO, Fletcher, NC [2011], Knoxville, TN, Dallas, TX, and Blacksburg, VA). KSUZ 0802 had a significantly finer leaf texture than Chisholm and statistically

Table 2. Establishment of KSUZ 0802 and two commercial zoysiagrass cultivars at nine locations.

| Cultivar | Establishment (% plot cover)† | | | | | | | | | |
|-----------|-------------------------------|---------|--------|--------|--------|--------|--------|---------|--------|------|
| | KS1 | MO | NC1 | NC2 | OK | TN | TX | VA1 | VA2 | TPI‡ |
| | % | | | | | | | | | |
| KSUZ 0802 | 87.5 a§ | 79.7 ab | 55.0 a | 68.3 a | 71.0 a | 97.3 a | 73.3 a | 63.3 ab | 70.2 a | 9 |
| Chisholm | 86.7 a | 85.0 a | 51.7 a | 70.0 a | 79.0 a | 99.2 a | 70.0 a | 74.0 a | 74.4 a | 9 |
| Meyer | 76.2 b | 76.0 b | 41.7 a | 45.0 a | 81.3 a | 91.2 b | 73.3 a | 53.0 b | 67.1 a | 5 |

† Entries were planted in summer 2009, except in two North Carolina locations, which were planted in summer 2010. Establishment was visually assessed as a percentage of plot cover from 0 to 100%. Means were determined from 2010 data across three replications at seven locations: Wichita, KS (KS1) (June–Oct.), Fletcher, NC (NC1) (Oct.), Jackson Springs, NC (NC2) (Oct.), Stillwater, OK (Apr., June–July, Sept.–Oct.), Knoxville, TN (June–Aug., Sept. [twice], Oct.), Virginia Beach, VA (VA1) (Apr.–May, July–Sept.), and Blacksburg, VA (VA2) (May–Aug.). Means presented for Columbia, MO, are averages from 2009 (Oct.–Nov.), and means presented for Dallas, TX, are averages from 2012 (June).

‡ TPI (turfgrass performance index) was determined as the number of times each cultivar appeared in the top statistical group.

§ Means in a column followed by the same letter(s) are not significantly different according to Fisher's Protected LSD test ($P \leq 0.05$).

Table 3. Turf quality of KSUZ 0802 and two commercial zoysiagrass cultivars at nine locations maintained at lawn height of cut (3.8 to 6.4 cm).

| Cultivar | Turf quality† | | | | | | | | | | | | | | | TPI‡ | |
|-----------|---------------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|--------|-------|--------|-------|-------|------|
| | KS1 | | | MO | NC1 | NC2 | OK | | | TN | TX | | VA1 | VA2 | | | |
| | 2010 | 2011 | 2012 | | | | 2010 | 2011 | 2012 | | 2011 | 2012 | | 2010 | 2011 | | 2012 |
| | 1–9 | | | | | | | | | | | | | | | | |
| KSUZ 0802 | 5.3 a§ | 5.6 a | 4.5 a | 6.1 a | 7.4 a | 5.7 a | 5.0 a | 7.1 a | 7.1 a | 6.6 a | 4.6 b | 3.0 ab | 7.2 a | 5.7 a | 6.5 a | 6.2 a | 15 |
| Chisholm | 5.1 a | 5.2 a | 5.3 a | 6.2 a | 5.4 b | 5.4 ab | 5.1 a | 6.0 b | 6.0 b | 6.5 a | 5.5 a | 3.7 a | 6.9 a | 5.4 ab | 6.3 a | 5.6 b | 12 |
| Meyer | 3.9 b | 5.2 a | 3.3 b | 5.3 a | 7.3 a | 5.0 b | 5.1 a | 6.1 b | 6.1 b | 6.5 a | 3.6 c | 2.3 b | 7.0 a | 4.7 b | 4.9 b | 5.1 b | 6 |

† Turf quality was assessed on a 1-to-9 scale, where 1 = poor, and 9 = ideal. Means were determined across three replications at nine test locations: Wichita, KS (KS1), 2010 (May–Sept.), 2011 (May–Sept.) and 2012 (May–Sept.); Columbia, MO, 2010 (May, July), 2011 (June), and 2012 (Sept.); Fletcher, NC (NC1), 2011 (June–Sept.) and 2012 (May–Oct.); Jackson Springs, NC (NC2), 2011 (May–Oct.) and 2012 (May–Oct.); Stillwater, OK, 2010 (May, Aug.–Oct.), 2011 (May–Oct.), and 2012 (Apr.–July, Oct.); Knoxville, TN, 2010 (July–Aug., Sept. [twice], Oct.) and 2011 (May–June, Aug.–Sept.); Dallas, TX, 2011 (May–Oct.) and 2012 (May [twice], June); Virginia Beach, VA (VA1), 2010 (Aug.–Sept.), 2011 (May–Oct.), and 2012 (May–Oct.); and Blacksburg, VA (VA2), 2010 (July–Aug., Sept. [twice], Oct.), 2011 (May–Sept.), and 2012 (May–Oct.). Years are presented separately for locations with a significant cultivar × year interaction in the ANOVA.

‡ TPI (turfgrass performance index) was determined as the number of times each cultivar appeared in the top statistical group.

§ Means in a column followed by the same letter(s) are not significantly different according to Fisher's protected LSD test ($P \leq 0.05$).

similar leaf texture to Meyer in five analyses (Fletcher, NC, Jackson Springs, NC, Stillwater, OK, and Virginia Beach, VA). KSUZ 0802 was in the top statistical group in all 11 analyses compared with Meyer (TPI = 5) and Chisholm (TPI = 0).

Genetic Color

A significant cultivar × year interaction for genetic color was not present at any of the nine locations (Table 5). The genetic color of KSUZ 0802 was similar to Meyer and Chisholm in Jackson Springs, NC; Knoxville, TN; Dallas, TX and Blacksburg, VA; superior (darker green) to Meyer in Stillwater, OK; and superior to Chisholm in Wichita, KS; Columbia, MO and Fletcher, NC. KSUZ was in the top

statistical group in all nine locations as compared to Meyer (TPI = 8) and Chisholm (TPI = 5).

Spring Green-Up

For spring green-up, a significant ($P < 0.05$) cultivar × year effect occurred in three locations (Wichita, KS, Knoxville, TN, and Blacksburg, VA) (Table 6). The spring green-up of KSUZ 0802 was similar to Meyer and Chisholm in seven analyses (Wichita, KS [2010], Columbia, MO, Fletcher, NC, Stillwater, OK, Knoxville, TN, Dallas, TX, and Virginia Beach, VA). KSUZ 0802 was superior to Chisholm in Wichita, KS (2011, 2012), and was superior to Meyer in Wichita, KS (2012), and Blacksburg, VA. In Jackson Springs, NC, Meyer and Chisholm had superior spring green-up compared with KSUZ 0802.

Table 4. Leaf texture of KSUZ 0802 and two commercial zoysiagrass cultivars at nine locations maintained at lawn height of cut (3.8 to 6.4 cm).

| Cultivar | Leaf texture† | | | | | | | | | | | TPI‡ |
|-----------|---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| | KS1 | MO | NC1 | | | NC2 | OK | TN | TX | VA1 | VA2 | |
| | | | 2010 | 2011 | 2012 | | | | | | | |
| 1–9 | | | | | | | | | | | | |
| KSUZ 0802 | 7.4 a§ | 6.0 a | 7.0 a | 8.0 a | 8.0 a | 6.9 a | 6.7 a | 7.7 a | 6.0 a | 7.7 a | 6.7 a | 11 |
| Chisholm | 5.2 b | 4.0 c | 5.7 b | 5.0 c | 5.7 b | 5.1 b | 2.0 b | 5.0 c | 4.7 c | 3.7 b | 3.3 c | 0 |
| Meyer | 5.7 b | 5.0 b | 7.0 a | 7.0 b | 7.7 a | 7.6 a | 5.3 a | 6.7 b | 5.5 b | 6.7 a | 5.0 b | 5 |

† Leaf texture was assessed once each year on a 1-to-9 scale, where 1 = very coarse, and 9 = very fine. Means were determined across three replications at nine test locations: Wichita, KS (KS1), 2010 (Sept.), 2011 (July), and 2012 (July); Columbia, MO, 2009 (Oct.); Fletcher, NC (NC1), 2010 (Oct.), 2011 (Aug.), and 2012 (July); Jackson Springs, NC (NC2), 2010 (Oct.), 2011 (July), and 2012 (July); Stillwater, OK, 2009 (Sept.); Knoxville, TN, 2009 (Sept.); Dallas, TX, 2011 (May) and 2012 (May); Virginia Beach, VA (VA1), 2010 (July); and Blacksburg, VA (VA2), 2010 (July). Years are presented separately for locations with a significant cultivar × year interaction in the ANOVA.

‡ TPI (turfgrass performance index) was determined as the number of times each cultivar appeared in the top statistical group.

§ Means in a column followed by the same letter(s) are not significantly different according to Fisher's protected LSD test ($P \leq 0.05$).

Table 5. Genetic color of KSUZ 0802 and two commercial zoysiagrass cultivars at nine locations maintained at lawn height of cut (3.8–6.4 cm).

| Cultivar | Genetic color† | | | | | | | | | | TPI‡ |
|-----------|----------------|-------|-------|-------|--------|-------|-------|--------|-------|-----|------|
| | KS1 | MO | NC1 | NC2 | OK | TN | TX | VA1 | VA2 | | |
| | | | | | | | | | | 1–9 | |
| KSUZ 0802 | 5.7 a§ | 7.3 a | 7.2 a | 5.8 a | 8.0 a | 7.3 a | 7.0 a | 7.3 ab | 5.7 a | 9 | |
| Chisholm | 4.4 b | 5.8 b | 4.8 b | 5.5 a | 7.3 ab | 7.7 a | 7.0 a | 7.0 b | 6.0 a | 5 | |
| Meyer | 6.1 a | 7.3 a | 7.3 a | 6.7 a | 7.0 b | 6.3 a | 7.7 a | 8.0 a | 4.3 a | 8 | |

† Genetic color was assessed on a 1-to-9 scale, where 1 = brown/dead, and 9 = dark green. Means were determined across three replications at nine test locations: Wichita, KS (KS1), 2010 (Sept.), 2011 (July), and 2012 (July); Columbia, MO, 2011 (June) and 2012 (Sept.); Fletcher, NC (NC1), 2011 (Aug.) and 2012 (July); Jackson Springs, NC (NC2), 2011 (July) and 2012 (July); Stillwater, OK, 2009 (Sept.); Knoxville, TN, 2009 (Sept.); Dallas, TX, 2011 (June); Virginia Beach, VA (VA1), 2011 (July); and Blacksburg, VA (VA2), 2010 (July). In the ANOVA, cultivar × year interaction was not significant for any location.

‡ TPI (turfgrass performance index) was determined as the number of times each cultivar appeared in the top statistical group.

§ Means in a column followed by the same letter(s) are not significantly different according to Fisher's protected LSD test ($P \leq 0.05$).

Table 6. Spring green-up of KSUZ 0802 and two commercial zoysiagrass cultivars at nine locations maintained at lawn height of cut (3.8–6.4 cm).

| Cultivar | Spring green-up† | | | | | | | | | | | | TPI‡ | |
|-----------|------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|----|
| | KS1 | MO | NC1 | NC2 | OK | TN | | TX | VA1 | VA2 | | | | |
| | | | | | | 2010 | 2011 | | | 2011 | 2012 | | | |
| 1–9 | | | | | | | | | | | | | | |
| KSUZ 0802 | 4.3 a§ | 6.7 a | 5.3 a | 6.8 a | 7.8 a | 5.2 b | 2.8 a | 6.3 a | 9.0 a | 4.0 a | 6.0 a | 5.0 a | 8.0 a | 12 |
| Chisholm | 4.3 a | 5.3 b | 3.7 b | 8.1 a | 7.7 a | 7.2 a | 3.0 a | 7.3 a | 9.0 a | 4.7 a | 5.8 a | 4.0 ab | 8.0 a | 11 |
| Meyer | 3.0 a | 7.3 a | 4.0 b | 6.8 a | 7.8 a | 6.7 a | 3.3 a | 6.2 a | 9.0 a | 4.7 a | 6.2 a | 2.7 b | 6.7 b | 10 |

† Spring green-up was assessed once during the spring as the overall plot color on a 1-to-9 scale, where 1 = brown/dead, and 9 = dark green. Means were determined across three replications at nine test locations: Wichita, KS, 2010 (Apr.), 2011 (Apr.) and 2012 (May); Columbia, MO, 2010 (Apr., May [twice]) and 2011 (June); Fletcher, NC (NC1), 2011 (Apr.) and 2012 (Apr.); Jackson Springs, NC (NC2), 2011 (Apr.) and 2012 (Mar.); Stillwater, OK, 2010 (Mar., Apr.); Knoxville, TN, 2010 (Apr. [twice]) and 2011 (Apr.); Dallas, TX, 2011 (Mar.); Virginia Beach, VA (VA1), 2010 (Mar.), 2011 (Apr./Mar.), and 2012 (Mar.); and Blacksburg, VA (VA2), 2011 (Apr.) and 2012 (Apr.). Years are presented separately for locations with a significant cultivar × year interaction in the ANOVA.

‡ TPI (turfgrass performance index) was determined as the number of times each cultivar appeared in the top statistical group.

§ Means in a column followed by the same letter(s) are not significantly different according to Fisher's protected LSD test ($P \leq 0.05$).

Overall, KSUZ 0802 was in the top statistical group 12 times compared with Chisholm (TPI = 11) and Meyer (TPI = 10).

Fall Color Retention

Data for fall color retention were collected at six of the nine test locations (Table 7). In three of the locations (Wichita, KS, Columbia, MO, and Jackson Springs, NC), fall color retention ratings for cultivars varied significantly across years. No significant differences were observed for fall color retention between KSUZ 0802, Meyer, and Chisholm in Columbia, MO, Fletcher, NC, Jackson Springs, NC (2012), Stillwater, OK, or Dallas, TX. KSUZ 0802 was statistically similar to Meyer and Chisholm in Wichita, KS (2012), and Jackson Springs, NC (2011), but Chisholm was superior to KSUZ 0802 in Wichita, KS (2010), and Meyer was superior to KSUZ 0802 in Jackson Springs, NC (2010). Fall color retention is a desirable trait extending the green appearance of the turf stand into the autumn season; however, early fall dormancy and associated loss of green color (low fall color retention ratings) has been shown to be directly related to increased freezing tolerance (Fry and Huang, 2004).

Characteristics at Golf Course Fairway Height (1.3 cm)

KSUZ 0802, Meyer, and Chisholm were maintained at a fairway height in Manhattan, KS (KS2) and Stillwater, OK (Table 8). In Stillwater, OK, the turf quality of KSUZ 0802 was similar to Meyer and Chisholm in 2010 but was superior in 2011 and 2012. In Wichita, KS, KSUZ 0802 was similar to Meyer and superior to Chisholm in 2008, but in 2009, 2010, and 2011, KSUZ 0802 and Chisholm were statistically superior to Meyer. When cut at fairway height, KSUZ 0802 also had finer leaf texture than Meyer and Chisholm in Stillwater, OK, and Wichita, KS. The genetic color of KSUZ 0802 as assessed in Manhattan, KS, was similar to Chisholm and Meyer in 2009 and 2010 but lighter green than both cultivars in 2011. Spring green-up of KSUZ 0802 in Stillwater, OK, was similar to Chisholm but slower than Meyer. The fall color retention was the same for all three cultivars in both locations. Recovery of KSUZ 0802 from stolons and rhizomes as determined by percentage area covered after sod harvest in Manhattan (2008 and 2009) and Olathe, KS (2009 and 2010), was similar to Meyer and Chisholm (Okeyo et al., 2010).

Table 7. Fall color retention of KSUZ 0802 and two commercial zoysiagrass cultivars at six locations maintained at lawn height of cut (3.8–6.4 cm).

| Cultivar | Fall color retention† | | | | | | | | | | TPI‡ | | | |
|-----------|-----------------------|--------|-------|-------|-------|-------|-------|--------|-------|-------|-------|----|----|------|
| | KS1 | | MO | | | NC1 | | | NC2 | | | OK | TX | |
| | 2010 | 2012 | 2009 | 2010 | 2011 | 2010 | 2011 | 2012 | 2010 | 2011 | | | | 2012 |
| KSUZ 0802 | 3.7 b§ | 2.2 ab | 3.8 a | 5.5 a | 3.7 a | 7.0 a | 6.3 b | 3.8 b | 6.0 a | 4.3 a | 4.3 a | 8 | | |
| Chisholm | 5.7 a | 1.8 b | 4.3 a | 5.3 a | 4.3 a | 5.8 a | 6.0 b | 6.5 a | 7.3 a | 4.7 a | 5.0 a | 9 | | |
| Meyer | 4.0 b | 3.1 a | 3.0 a | 5.7 a | 4.7 a | 7.0 a | 8.7 a | 5.0 ab | 7.3 a | 5.0 a | 3.7 a | 10 | | |

† Fall color retention was assessed once during the fall on a 1-to-9 scale, where 1 = brown/dead, and 9 = dark green. Means were determined across three replications at six test locations: Wichita, KS (KS1), 2010 (Oct.) and 2012 (Oct., Nov. [twice]); Columbia, MO, 2009 (Oct., Nov.), 2010 (Oct. [twice]), and 2011 (Oct.); Fletcher, NC (NC1), 2010 (Oct.) and 2012 (Oct.); Jackson Springs, NC (NC2), 2010 (Oct.), 2011 (Oct., Nov.), and 2012 (Oct.); Stillwater, OK, 2010 (Oct.); and Dallas, TX, 2011 (Nov.). Years are presented separately for locations with a significant cultivar × year interaction in the ANOVA.

‡ TPI (turfgrass performance index) was determined as the number of times each cultivar appeared in the top statistical group.

§ Means in a column followed by the same letter(s) are not significantly different according to Fisher's protected LSD test ($P \leq 0.05$).

Table 8. Performance of KSUZ 0802 and commercial zoysiagrass cultivars mowed at fairway height (1.3 cm) at two locations.

| Cultivar | Turf quality† | | | | | | | | | | Leaf texture‡ | | Genetic color§ | | | Spring green-up¶ | | Fall color retention# | | Billbug damage†† | | TPI‡‡ |
|-----------|---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------------|-------|----------------|-------|-------|------------------|--------|-----------------------|------|------------------|--|-------|
| | KS2 | | | | | | OK | | | | KS2 | OK | KS2 | OK | KS2 | OK | KS2 | OK | | | | |
| | 2008 | 2009 | 2010 | 2011 | 2010 | 2011 | 2012 | 2009 | 2010 | 2011 | | | | | | | | | 2009 | 2010 | | |
| KSUZ 0802 | 8.0 a§§ | 6.3 a | 7.1 a | 7.2 a | 5.4 a | 7.6 a | 6.6 a | 8.0 a | 7.3 a | 5.0 a | 4.0 a | 2.7 b | 3.7 b | 4.0 a | 5.7 a | 14.1 b | 2.8 b | 14 | | | | |
| Chisholm | 6.0 b | 5.9 a | 6.5 a | 6.6 a | 4.9 a | 6.2 b | 6.1 b | 5.0 c | 2.0 c | 4.8 a | 4.0 a | 4.0 a | 3.0 b | 4.6 a | 5.3 a | 0.0 c | 0.0 b | 11 | | | | |
| Meyer | 7.0 ab | 4.8 b | 5.5 b | 5.6 b | 5.0 a | 6.1 b | 5.6 c | 6.3 b | 4.7 b | 5.3 a | 5.3 a | 4.0 a | 5.5 a | 4.1 a | 5.7 a | 31.7 a | 12.2 a | 8 | | | | |

† Turf quality ratings were assessed on a 1-to-9 scale, where 1 = poor, and 9 = ideal. Means were determined across three replications at two test locations: Manhattan, KS (KS2), 2008 (Sept.), 2009 (June–Aug.), 2010 (May–Sept.), and 2011 (May, July–Sept.); and Stillwater, OK, 2010 (May, Aug., Sept., Oct.), 2011 (May–Oct.), and 2012 (Apr.–July, Oct.). Years are presented separately for locations with a significant cultivar × year interaction in the ANOVA.

‡ Leaf texture was assessed once each year on a 1-to-9 scale, where 1 = very coarse, and 9 = very fine. Means were determined across three replications at two test locations: Manhattan, KS (KS2), 2008 (Sept.), 2009 (June), and 2011 (Aug.); and Stillwater, OK, 2009 (Sept.).

§ Genetic color was rated on a 1-to-9 scale, where 1 = light green, and 9 = dark green, in Manhattan, KS (KS2), 2009 (Apr., June), 2010 (Apr. [twice]), and 2011 (Apr.).

¶ Spring green-up was assessed on a 1-to-9 scale, where 1 = brown/dead, and 9 = dark green, in Stillwater, OK, 2010 (Mar.–Apr.).

Fall color retention was assessed once during the fall on a 1-to-9 scale, where 1 = brown/dead, and 9 = dark green. Means were determined across three replications at two test locations: Manhattan, KS (KS2), 2008 (Oct., Nov.), 2009 (Oct.), 2010 (Oct.), and 2011 (Oct.); and Stillwater, OK, 2010 (Oct.).

†† Billbug damage was assessed as a percentage of plot damage in 2009 (July and Aug.) and 2010 (June–Sept.) in the Manhattan, KS, location (Fry and Cloyd, 2011).

‡‡ TPI (turfgrass performance index) was determined as the number of times each cultivar appeared in the top statistical group for traits rated 1–9 and in the bottom statistical group for billbug damage.

§§ Means in a column followed by the same letter(s) are not significantly different according to Fisher's protected LSD test ($P \leq 0.05$).

Meyer is susceptible to bluegrass billbug injury, and Chisholm has been shown to exhibit excellent resistance (Chandra et al., 2015). Data collected at Manhattan, KS (Table 8; Fry and Cloyd, 2011), demonstrated that KSUZ 0802 had significantly less bluegrass billbug damage than Meyer in 2009 and 2010. KSUZ 0802 had more billbug damage than Chisholm in 2009 but was similar to Chisholm, with little to no damage, in 2010.

The freezing tolerance studies conducted at Manhattan, KS (Okeyo et al., 2011b), showed KSUZ 0802 had an LT₅₀ statistically similar to Meyer and Chisholm in both 2007 and 2008. Observed LT₅₀s ranged from -8.4 to -10.3°C for KSUZ 0802 and from -10.7 to -12.0°C for Meyer. These results support the suitability of KSUZ 0802 for golf course tees and fairways maintained at low mowing heights.

Conclusions

KSUZ 0802 is an interspecific hybrid developed from a cross between *Z. matrella* cultivar Cavalier and *Z. japonica* ecotype Anderson 1. It has finer leaf texture and superior turf quality than Meyer with freezing tolerance similar to Meyer. Out of a possible TPI score of 86, KSUZ 0802 received the highest score of 78 compared with Chisholm (57) and Meyer (52). KSUZ 0802 is well suited for golf course tees and fairways and home lawns in the transition zone.

Availability

Texas A&M AgriLife Research–Dallas, TX, will maintain breeder stock of KSUZ 0802. Only foundation, registered, and certified classes of sod are recognized for KSUZ 0802. All certified production must be directly from registered, foundation, or breeder stock. Vegetative propagules of KSUZ 0802 are available from the corresponding author for research purposes. Samples of KSUZ 0802 have been deposited at the USDA-ARS National Center for Genetic Resource Preservation, where they will be available for public distribution after the expiration of the plant patent.

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