Research Reports

Strategies for Converting Tall Fescue to Warm-season Turf in a Mediterranean Climate

Marco Schiavon¹, Brent D. Barnes¹, David A. Shaw²,
J. Michael Henry³, and James H. Baird^{1,4}

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SUMMARY. Replacing cool-season turf with more drought and heat tolerant warm-season turfgrass species is a viable water conservation strategy in climates where water resources and precipitation are limited. Field studies were conducted in Riverside and Irvine, CA, to investigate three methods (scalping, eradication with a nonselective herbicide, planting into existing turf) of converting an existing tall fescue (*Festuca arundinacea*) sward to warm-season turf. Cultivars established vegetatively by plugging were 'De Anza' hybrid zoysiagrass [*Zoysia matrella* × (*Z. japonica* × *Z. tenuifolia*)], 'Palmetto' st. augustinegrass (*Stenotaphrum secundatum*), 'TifSport' hybrid bermudagrass (*Cynodon dactylon* × *C. transvaalensis*), 'Sea Spray' seashore paspalum (*Paspalum vaginatum*), and 'UC Verde' buffalograss (*Buchloe dactyloides*). Cultivars established from seeds were 'Princess-77' bermudagrass (*C. dactylon*) and 'Sea Spray' seashore paspalum. Neither scalping nor planting into existing tall fescue were effective conversion strategies, as none of the warm-season turfgrasses reached 50% groundcover within 1 year of planting. All of the species except for st. augustinegrass reached a higher percentage of groundcover at the end of the study when glyphosate herbicide was applied to tall fescue before propagation compared with the other conversion strategies. Bermudagrass and seashore paspalum established from seeds and hybrid bermudagrass from plugs provided the best overall establishment with 97%, 93%, and 85% groundcover, respectively, when glyphosate was used before establishment. Quality of seeded cultivars matched or exceeded that of cultivars established vegetatively by plugging. These results suggest that eradication of tall fescue turf followed by establishment of warm-season turf from seeds is the best and easiest turf conversion strategy.

Increasing urban expansion in the southwestern United States will result in higher demands for potable water. Limited annual precipitation causing periodic droughts and

scarcity of surface water sets the priority on the allocation of potable water resources, and in turn limits the amount of water that can be used for nonhuman consumption. Turfgrass is considered a nonessential crop, as it does not provide food or nutrition for humans, therefore water that can be allocated for outdoor landscape irrigation is often restricted (City of Albuquerque, NM, 2000; State of California, 2009). Decreasing water

supplies and current or impending water use restrictions throughout California and the southwestern United States demand serious and demonstrable efforts to conserve water among end users, especially on outdoor landscapes. These days, it is common for municipalities and water agencies to offer their customers monetary incentives for replacing turf with alternative, drought tolerant landscape plants or xeriscape materials (Metropolitan Water District of Southern California, 2013).

Tall fescue is the most common turfgrass species used on lawns in California and other regions in the southwestern United States because it retains green color throughout the year as long as supplemental irrigation is provided in the summer. Although one of the most drought tolerant (avoidant) cool-season turfgrass species because of deep rooting, tall fescue has a high water use rate (Fry and Huang, 2004). Richie et al. (2002) found that tall fescue required on average 80% crop evapotranspiration (ET_{crop})/irrigation uniformity [where ET_{crop} = reference evapotranspiration (ET_o) × crop coefficient (K_c)] to maintain acceptable turf in Riverside, CA. This translates into an annual irrigation requirement for tall fescue (including natural precipitation) of ≈46 and 36 inches in Riverside and Irvine, CA, respectively (Green, 2005).

Converting preexisting cool-season to warm-season turf swards is one strategy that can potentially save up to 20% or more water, based on differences in ET and drought tolerance (Huang and Fry, 1999; Meyer et al., 1985). Evapotranspiration rates reported in the literature for warm-season species range from 3 to 9 mm·d⁻¹, while rates for cool-season turfgrasses typically range between 4 and 13 mm·d⁻¹ (Kenna, 2008). In Texas, tall fescue can use up to 47% more water than zoysiagrass [*Zoysia japonica* (Kim, 1983)]. Transitioning from cool-season to warm-season turf species has helped golf course superintendents to reduce pest management and irrigation costs (Zuk and Fry, 2006).

Regardless of potential water savings, the conversion of an existing cool-season turf into warm-season turf can be problematic. Removing the existing sod and replacing sod of a warm-season species would be the ideal remedy, but this may be cost

¹Department of Botany and Plant Sciences, University of California, Riverside, CA 92521

²University of California Cooperative Extension, 151 E. Carmel Street, San Marcos, CA 92708

³University of California Cooperative Extension, 21150 Box Spring Road, Suite 202, Moreno Valley, CA 92557

⁴Corresponding author. E-mail: jlbaird@ucr.edu.

prohibitive for many homeowners and facilities. An alternative approach would be to seed or plug the warm-season species directly into the existing sward. In this case, competition among species needs to be either reduced or removed to allow the new turf to establish. Therefore, identification of methods to convert cool-season into warm-season stands would be helpful to those who wish to minimize turf maintenance costs in addition to reducing irrigation water use.

Interseeding a new species into a preexisting one is the simplest approach to replace cool-season species. Interseeding has minimal impact on activity and therefore it will not involve loss of revenue or aesthetics. However, competition for resources, including light, water, and nutrients, may prevent the interseeded species from germination and establishment. A maximum of 2% coverage was achieved in a study conducted in Indiana and Kentucky when zoysiagrass was interseeded into perennial ryegrass (*Lolium perenne*) without prior herbicide application (Patton et al., 2004). In another study, zoysiagrass cover reached only 9% when the existing perennial ryegrass sward was not treated with either an herbicide or a plant growth regulator (Zuk and Fry, 2005). Similarly, greater bermudagrass cover was reported if herbicides were applied to perennial ryegrass stands before seeding for species transition (Jellicorse et al., 2012; Williams and Burrus, 2004). Jellicorse et al. (2012) concluded that trying to establish bermudagrass on top of a perennial ryegrass sward is not effective unless the cool-season grass is eradicated first with an herbicide.

Several studies showed that applying glyphosate (Roundup Pro; Monsanto, St. Louis, MO), a nonselective herbicide, before seeding is the fastest and most efficient method to convert cool-season to warm-season turf areas (Fry et al., 2007; Jellicorse et al., 2012; Patton et al., 2004; Williams and Burrus, 2004; Zuk and Fry, 2005). Glyphosate applications immediately before seeding had little or no negative effect on germination and establishment (Egley and Williams, 1978; Hurto and Turgeon, 1978; Kaufman, 1978; Kollenkark and Daniel, 1978; Marshall and Naylor, 1984). However, some studies reported a significant loss in turfgrass quality

during the transition period from perennial ryegrass to bermudagrass when glyphosate was applied before seeding (Jellicorse et al., 2012; Williams and Burrus, 2004). Similarly, Mittlesteadt et al. (2009) reported that turfgrass quality dropped below acceptable levels when glyphosate was used to remove a kentucky bluegrass (*Poa pratensis*) and perennial ryegrass mixture before bermudagrass seeding. Moreover, glyphosate application will impact aesthetic turf quality during conversion and could require closure of the treated area with a consequent loss of revenue. The cost of the herbicide and seeds might be prohibitive as well (Fry et al., 2007).

Scalping taller cut cool-season turf such as tall fescue before interseeding can help hasten warm-season turfgrass establishment. Zuk and Fry (2005) demonstrated that seeded zoysiagrass coverage at the end of a 3-year study was similar between scalping and glyphosate treatments. However, the plots had to be scalped three times per week at 0.6 cm for several weeks, until zoysiagrass tillering.

Previous studies investigating the efficacy of converting cool-season into warm-season turf stands included only one species at a time, without determining which warm-season species and establishment method might be the most suitable in replacing cool-season turfgrasses. Objectives of this study were to determine the speed and efficacy of five different warm-season turfgrasses established either from seeds or vegetatively from plugs in replacing a cool-season tall fescue sward using three different conversion methods (scalping, glyphosate, planting into existing turf) in inland and coastal climates of southern California.

Materials and methods

A study was conducted from June 2009 to May 2010 at the University of California, Riverside Turfgrass

Research Facility [Riverside, CA; U.S. Department of Agriculture (USDA) plant hardiness zone 9b], and at the South Coast Research and Extension Center (Irvine, CA; USDA plant hardiness zone 10a). The soil at Riverside was a Hanford fine sandy loam (70.4% sand, 19.8% silt, 9.8% clay, superactive, nonacid, thermic Typic Xerorthents), with 0.6% organic matter. The soil at Irvine was a San Emigdio loamy sand (53% sand, 28% silt, 19% clay, calcareous, thermic, Typic Xerifluvents), with 1.0% organic matter.

The studies were conducted on mature existing turf-type tall fescue turf maintained under lawn conditions. Before the experiments started, turf was mowed one or two times per week at 2 inches using a rotary mower. The sward was irrigated at 100% ET₀ to maintain green color and appealing visual quality. Turf received 5 lb/1000 ft² nitrogen (N) per year using a 15N-6.5P-12K fertilizer.

Two conversion methods from tall fescue to warm-season species were tested against a no-removal (turf left intact) control. Before warm-season establishment, tall fescue was treated with the nonselective herbicide glyphosate at a rate of 2 qt/acre on 18 June 2009 in Riverside and on 14 July 2009 in Irvine, or scalped down to 3/4 inch, the lowest setting using a rotary mower. Turf was left in place following herbicide application, and leaf debris was raked and removed following scalping. Nontreated tall fescue maintained at 2 inches served as a control. Propagation of warm-season turfgrasses took place the day after herbicide application and scalping in both locations. Five species were selected for the study: hybrid bermudagrass ('Tifsport'), bermudagrass ('Princess-77'), buffalograss ('UC Verde'), seashore paspalum ('Sea Spray'), st. augustinegrass ('Palmetto'), and hybrid zoysiagrass ('De Anza'). 'Sea Spray' seashore paspalum was

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
0.0929	ft ²	m ²	10.7639
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
48.8243	lb/1000 ft ²	kg·ha ⁻¹	0.0205
1.1209	lb/acre	kg·ha ⁻¹	0.8922
2.3385	qt/acre	L·ha ⁻¹	0.4276
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

established both from seeds and vegetatively by plugging. 'Princess-77' bermudagrass was established by seeds only. Seeding rate was 1 lb/1000 ft² of pure live seed broadcasted after the plots were aerated using 0.25-inch-diameter solid tines. The remaining five cultivars were vegetatively propagated using 1.25-inch-diameter plugs planted on 1-ft spacing. 'UC Verde' buffalograss is commercially available as plugs only; hence, the plugging comparison among all nonseeded species. Furthermore, commercial recommendations at the time were that buffalograss could be plugged directly into living tall fescue lawns. Therefore, an untreated, no-removal control was included for comparison.

Following propagation, the plots were syringed lightly five times per day for 3 weeks to hasten turf establishment. Irrigation was then reduced to 80% ET_o/distribution uniformity to favor warm-season species over tall fescue. The scalped or glyphosate plots were mowed one or two times

weekly at 1.5 inches with a reel mower (Tru-Cut; Dolphin Outdoor Power Equipment, Pompano Beach, FL). The control plots were mowed one or two times weekly at 2 inches with a rotary mower. In 2009, all plots received a total of 2.5 lb/1000 ft² N and 2 lb/1000 ft² potassium (K) from June to October using an 18N-0P-14.9K fertilizer. The following year, an additional 1.5 and 1.2 lb/1000 ft² K were provided to the plots from March to May with the same fertilizer. All plots received 0.25 lb/1000 ft² phosphorus (P) in Mar. 2010 only using a 0N-20.1P-0K fertilizer. Initially, weeds were controlled by hand; however, eventually broadleaf weed pressure reached a point where herbicide control was necessary. A mixture of carfentrazone, 2,4-D, mecoprop and dicamba was applied at a rate of 0.01, 0.13, 0.05, and 0.01 lb/acre acid equivalent, respectively, on 11 Oct. 2009.

Treatments were arranged in a completely randomized block design. Plot size was 49 ft² and each treatment

was replicated three times. Since there was a 26-d shift between planting dates of the two locations, days after planting (DAP) were calculated for each location and data were analyzed separately for each DAP. Visual estimation of warm-season turf cover was conducted each month starting from 100 DAP until dormancy for each location; this led to a total of two observation dates before the end of 2009. Turf visual quality on a scale from 1 to 9 (1 = worst, 9 = best) was taken starting 135 DAP. On 5 Mar. 2010, turf color and quality were assessed visually on the plots to calculate spring green-up. Percentage of groundcover was estimated using a 7 × 7-ft grid divided in 49 sections of 1 × 1 ft. The grid was laid on top of each plot and percent warm-season turf cover was visually estimated for each section; coverage for each section was used to calculate total coverage of each plot. A final visual estimation of warm-season cover and turf quality was done in 2010 at both locations at 345 DAP.

Table 1. Monthly average air temperatures, reference evapotranspiration (ET_o), and precipitation for Riverside and Irvine, CA, during the research period (June 2009 to May 2010) and for previous 25 years (1988–2012).

	June	July	August	September	October	November	December	January	February	March	April	May
Air temp (°C) ^z												
2009–2010 Riverside	19.6	25.3	24.4	24.7	18.4	15.9	11.4	12.7	12.6	14.5	14.3	17.1
1988–2012 Riverside	10.8	23.9	24.6	22.9	19.0	15.1	12.0	12.4	12.8	14.3	16.1	18.1
2009–2010 Irvine	20.1	23.8	24.2	24.1	19.7	17.4	13.2	14.3	13.9	14.1	13.9	15.9
1988–2012 Irvine	18.7	21.0	21.3	20.3	18.0	15.2	12.5	13.0	12.9	13.9	15.3	17.1
ET _o (mm) ^z												
2009–2010 Riverside	136	193	170	150	112	81	53	60	62	119	130	157
1988–2012 Riverside	166	183	175	136	103	75	65	63	74	106	134	151
2009–2010 Irvine	123	183	175	140	103	77	48	55	61	108	121	149
1988–2012 Irvine	149	160	156	116	93	66	57	55	63	93	120	132
Precipitation (mm)												
2009–2010 Riverside	0	0	0	0	0	3	45	135	51	8	24	2
1988–2012 Riverside	2	1	0	2	7	14	31	54	62	35	14	5
2009–2010 Irvine	0	0	0	0	1	0	32	10	80	14	38	1
1988–2012 Irvine	3	2	1	5	14	20	55	54	104	48	21	8

^z(1.8 × °C) + 32 = °F, 1 mm = 0.0394 inch.

Table 2. Results of analysis of variance testing on the effects of location (Riverside and Irvine, CA), grass species (hybrid bermudagrass, bermudagrass seeded, buffalograss, seashore paspalum, st. augustinegrass, and hybrid zoysiagrass) removal method (no removal, scalping, or glyphosate) and their interactions on warm-season cover and visual quality (1 = worst, 9 = best) at 100, 135, and 345 days after planting (DAP); turf color (1 = yellow/dormant grass, 9 = 100% green grass); and quality for spring green-up. Data were collected on 5 Mar. 2010.

Effect	100 DAP		135 DAP		345 DAP		Spring green-up	
	Cover (%)	Quality (1–9 scale)	Cover (%)	Quality (1–9 scale)	Cover (%)	Quality (1–9 scale)	Color	Quality (1–9 scale)
Location (L)	NS ^z	ND ^y	NS	***	NS	***	***	***
Grass (G)	***	ND	***	**	***	***	***	***
L × G	NS	ND	NS	*	***	***	***	***
Removal (R)	***	ND	***	***	***	***	***	***
L × R	NS	ND	NS	NS	NS	NS	***	***
G × R	***	ND	***	***	***	***	***	***
L × R × G	NS	ND	NS	NS	NS	NS	***	***

*, **, ***Significant F test at $P = 0.05$, 0.01 , and 0.001 level, respectively.

^zNon significant at $P = 0.05$ level.

^yNot determined due to missing values.

Turf quality and cover were subjected to analysis of variance separately for each DAP using SAS Proc Mixed (version 9.2; SAS Institute, Cary, NC). Where appropriate, means were followed by multiple comparisons using Fisher's protected least significant difference test at the 0.05 P level.

Results and discussion

Monthly average air temperatures, ET_o , and precipitation for the Riverside and Irvine locations are

provided in Table 1. Riverside is farther inland than Irvine and thus temperatures and ET_o are much higher during the summer months. However, winter temperatures are more moderate in Irvine because of its closer proximity to the Pacific Ocean. According to historical data, annual precipitation is typically greater in Irvine than Riverside, but not during the study period (Table 1).

WARM-SEASON TURF COVER. Warm-season turf cover was affected

by removal method and its interaction with warm-season species on 100, 135, and 345 DAP (Table 2). Therefore, data were pooled over location and are presented separately for each removal method and grass species. Glyphosate application resulted in complete death of tall fescue. The two cultivars established from seeds, 'Princess-77' and 'Sea Spray', established faster in comparison with all other treatments when glyphosate was applied before seeding. Seeded

Table 3. Percentage of warm-season species cover and visual quality (1 = worst, 9 = best) at 100, 135, and 345 days after planting (DAP) on plots converted from tall fescue to warm-season turf using three different removal methods (no removal, scalping, or glyphosate). Due to missing values, quality at 100 DAP was not determined. Data are pooled over two locations and three replications and represent an average of six data points.

Species	Removal	100 DAP	135 DAP		345 DAP	
		Cover (%)	Cover (%)	Quality (1–9 scale)	Cover (%)	Quality (1–9 scale)
Hybrid bermudagrass plugs	No removal	1 ef ^z	2 def	2.5 cde	14 efg	3.3 gh
	Scalping	1 ef	1 ef	4.1 a	29 cde	4.9 cdef
	Glyphosate	43 b	46 b	2.2 def	85 a	6.8 ab
Bermudagrass seeds	No removal	1 ef	1 ef	2.2 def	1 g	2.8 hi
	Scalping	1 ef	1 ef	2.8 cd	10 efg	3.8 fgh
	Glyphosate	58 a	67 a	2.3 def	97 a	6.0 bc
Buffalograss	No removal	2 ef	2 def	2.7 cd	4 g	1.8 ij
	Scalping	2 ef	2 def	3.0 bcd	4 g	3.2 gh
	Glyphosate	21 cd	32 bc	2.5 cde	39 bcd	5.7 cd
Seashore paspalum plugs	No removal	4 ef	5 def	2.5 cde	10 efg	3.3 gh
	Scalping	8 def	8 def	2.7 cd	17 defg	3.8 fgh
	Glyphosate	32 bc	38 b	2.3 def	55 b	4.8 ef
Seashore paspalum seeds	No removal	0 f	1 ef	2.2 def	1 g	1.2 j
	Scalping	15 de	16 cde	3.3 bc	28 cdef	2.0 ij
	Glyphosate	71 a	81 a	2.2 def	93 a	7.3 a
St. augustinegrass	No removal	0 f	0 f	2.2 def	5 g	2.1 i
	Scalping	4 ef	8 def	2.4 def	18 def	3.6 fgh
	Glyphosate	11 def	18 cd	1.8 f	41 bcd	4.1 ef
Hybrid zoysiagrass	No removal	1 ef	1 ef	2.0 ef	3 g	2.1 i
	Scalping	0 ef	1 ef	2.3 def	7 fg	2.5 i
	Glyphosate	9 def	13 de	2.2 def	46 bc	4.8 def

^zValues with the same letter in the same column are not significantly different from one another via Fisher's protected least significant difference at $P = 0.05$.

bermudagrass and seashore paspalum reached 67% and 81% of complete groundcover, respectively, by the end of 2009 and were the only two cultivars to reach >90% cover at the end of the study (Table 3). These results are in agreement with Schiavon et al. (2012) who documented that bermudagrass and seashore paspalum established equally fast when seeded in June. Moreover, these results confirm the suggestion of Patton et al. (2008) that seeding is not only less expensive but can also be faster than sprigging. These results are also in agreement with Munshaw et al. (1998) who reported faster bermudagrass establishment from seeds than from sprigs. Generally, warm-season species established faster and reached a higher percentage of groundcover 1 year after planting, if the tall fescue sward was treated with glyphosate before establishment. These results are in agreement with several studies conducted previously on the conversion from cool-season to warm-season turfgrasses (Fry et al., 2007; Jellicorse et al., 2012; Patton et al., 2004; Williams and Burrus, 2004; Zuk and Fry, 2005). However, scalping tall fescue was as effective as glyphosate application in establishment of st. augustinegrass. Plots that were scalped before establishment of st. augustinegrass yielded 4% groundcover at 100 DAP, 8% at 135 DAP, and 18% at the end of the study (Table 3), and these percentages were never different from the glyphosate-treated plots. It has been reported that st. augustinegrass is one of the most shade-tolerant warm-season turfgrasses (Busey, 2003). The ability to establish and grow under shade from the tall fescue canopy as it recovered from scalping may have been why st. augustinegrass cover did not differ between scalped and glyphosate-treated plots. Nevertheless, conversion to st. augustinegrass cannot be considered successful, as only 18% groundcover was reached when the tall fescue sward was scalped, and the glyphosate-treated plots did not reach 50% cover by the end of the study (Table 3). Zuk and Fry (2005) reported that scalping was as effective as applying glyphosate to convert perennial ryegrass to zoysiagrass. Nonetheless, with the exception of st. augustinegrass and seashore paspalum (plugged) in our study, warm-season turf cover in scalped plots did not significantly

differ from cover in intact tall fescue at 345 DAP. Moreover, at the end of the study the highest groundcover reached by a scalped tall fescue plot was only 29% by hybrid bermudagrass (Table 3). When plugged directly into live tall fescue, buffalograss reached only 4% groundcover in comparison with 39% cover when the tall fescue stand was treated with glyphosate (Table 3). This result was not different from that of hybrid zoysiagrass, st. augustinegrass, or seashore paspalum (all plugged).

The interaction of warm-season species and location was also significant at 345 DAP (Table 2). When data were averaged over removal method, hybrid bermudagrass reached the highest cover at the end of the study (Table 4). Seeded and plugged bermudagrass, and seashore paspalum also performed equally well in both locations. However, hybrid zoysiagrass and st. augustinegrass reached significantly higher cover in Riverside in comparison with Irvine, while buffalograss established better in Irvine than in Riverside. These results suggest that bermudagrass and seashore paspalum have a higher adaptability to different environments (coastal vs. inland) in comparison with the other warm-season turf species.

TURF VISUAL QUALITY. The interaction between removal method and grass species affected turf visual quality 135 and 345 DAP (Table 2). Therefore, data were pooled over location and presented separately for removal method and each grass species (Table 3). When turf quality was collected 135 DAP, warm-season grasses were entering dormancy. The highest quality was observed with hybrid bermudagrass (4.1) in plots that were scalped before planting (Table 3). Scalping tall fescue before seeding also had a positive effect on turf quality of seashore paspalum, but no differences between treatments were found in other cultivars (Table 3). These results are in partial agreement with Zuk and Fry (2005), who reported higher quality in a scalped perennial ryegrass sward converted to zoysiagrass in comparison with glyphosate treatment shortly after the beginning of the experiment. However, glyphosate-treated plots produced the highest quality with hybrid zoysiagrass (4.8), seeded bermudagrass (6.0), seeded seashore paspalum (7.3), hybrid

Table 4. Percentage of warm-season species cover 345 days after planting on plots converted from tall fescue to warm-season turf in Riverside and Irvine, CA. Data are pooled over three removal methods (no removal, scalping, or glyphosate) and three replications and represent an average of nine data points.

Species	Cover (%)	
	Riverside	Irvine
Hybrid bermudagrass	50 a ²	43 a
Bermudagrass seeds	35 b	36 b
Buffalograss	10 d	32 b
Seashore paspalum plugs	23 c	30 bc
Seashore paspalum seeds	37 ab	33 b
St.augustinegrass	33 b	9 d
Hybrid zoysiagrass	30 bc	8 d

²Values with the same letter are not significantly different from one another via Fisher's protected least significant difference at $P = 0.05$.

bermudagrass (6.8), and buffalograss (5.7) plots in comparison with scalping and the control at the end of the study (Table 3). Furthermore, glyphosate enhanced quality of seashore paspalum (plugged) in comparison with planting into existing turf (4.8 vs. 3.3). Moreover, plots treated with glyphosate rarely reached an acceptable quality level of 6 at the beginning of the study (Table 3). The highest quality was observed in seashore paspalum (seeded) and hybrid bermudagrass (plugged) plots; nevertheless, seeded bermudagrass quality was the same as plugged for each removal method. Therefore, it appears that new seeded cultivars of bermudagrass and seashore paspalum not only outperform older seeded cultivars (Shaver et al., 2006), but can also match the quality of top-performing vegetative cultivars (Morris 2002; Patton et al., 2009).

Location also had an effect on plot visual quality 135 and 345 DAP (Table 2). Quality was higher in Riverside 135 DAP in comparison with Irvine (data not shown). However, the difference between the two locations (2.8 in Riverside and 2.1 in Irvine) can be explained by the time difference between data collection. Quality ratings 135 DAP were taken on 1 Nov. 2009 in Riverside and on 27 Nov. 2009 in Irvine. Warm-season turfgrasses were in an advanced stage of dormancy when ratings were taken at the Irvine location compared with the earlier rating date in Riverside.

Also, turf visual quality was higher in Riverside in comparison with Irvine at the end of the study (data not shown). However, when data were pooled over removal method and warm-season species, turf quality did not reach an acceptable level of 6 at either location. Low ratings were probably because most of the warm-season turf did not establish properly, and groundcover on the majority of the plots was below 50% (Table 3). Brede and Duich (1986), investigating allelopathic interaction between cool-season species, concluded that dominance of a species in a mixture is a phenomenon that occurs both above and below ground. Above-ground growth can be affected by root interactions of different species. It is well documented that tall fescue possesses an aggressive, deep root system (Qian et al., 1997; Sheffer et al., 1987). Therefore, interaction of roots might have slowed the establishment of warm-season turfgrasses where tall fescue was not removed. Another possible explanation for slow turf establishment could be that the warm-season turfgrasses required

irrigation greater than 80% ET_o/distribution uniformity for successful establishment. More research is needed to investigate the relationship between turf cover and quality during the establishment of warm-season turfgrasses in a preexisting cool-season sward.

SPRING COLOR AND QUALITY. Location, removal method, warm-season species, and their interaction had a significant effect on warm-season turf color and plot visual quality during spring (Table 2). Among all cultivars and removal methods, hybrid bermudagrass green-up was faster on plots treated with glyphosate, with no differences between the two locations (Table 5). Seashore paspalum and seeded bermudagrass plots treated with glyphosate broke dormancy as fast as hybrid bermudagrass in Riverside, but not in Irvine. Removing the tall fescue sward with glyphosate resulted in higher color ratings for hybrid zoysiagrass, st. augustinegrass, seeded and hybrid bermudagrass, and seeded seashore paspalum in Riverside, and for seeded bermudagrass and seashore paspalum in Irvine (Table 5). These results suggest that eliminating

any competition during warm-season grass conversion leads to faster green-up in the spring. Plots that were scalped before establishment with hybrid zoysiagrass, seeded and hybrid bermudagrass, and plugged seashore paspalum greened-up faster in Irvine in comparison with Riverside. It has been suggested that scalping bermudagrass during the winter results in faster spring green-up by increasing soil temperatures (Rimi et al., 2011). Although soil temperatures were not recorded in our study, average air temperatures from November to February were higher in Irvine than in Riverside, which might have led to higher soil temperatures and therefore faster green-up.

The highest quality in March was observed in Riverside in glyphosate-treated plots, where either hybrid bermudagrass plugs or seashore paspalum seeds were planted, with a rating of 5.0 (Table 5). Glyphosate application before planting in Riverside also enhanced spring quality for hybrid zoysiagrass, st. augustinegrass, and seeded bermudagrass. Conversely, only plots converted from tall fescue to hybrid bermudagrass using glyphosate showed a significant improvement in turf quality in comparison with the other removal methods (Table 5). However, hybrid zoysiagrass, seeded seashore paspalum, and buffalograss plots treated with glyphosate in Irvine showed higher spring turf quality in comparison with planting into existing tall fescue (Table 5).

Conclusions

Converting preexisting cool-season turf to warm-season turf can save considerable water for outdoor use. According to our results, eradication of existing tall fescue turf with the nonselective herbicide glyphosate before planting is the best conversion method to warm-season turf in southern California. Glyphosate-treated plots not only achieved the highest groundcover at the end of the study but also exhibited the highest color and quality ratings in the following spring. Selection of a proper warm-season turfgrass species can be just as important as the turf conversion method. In our study, only bermudagrass and seashore paspalum resulted in a successful conversion and showed high adaptability to different environments. Moreover, seeded cultivars

Table 5. Warm-season turf color (1 = yellow/dormant grass, 9 = 100% green grass) and visual quality (1 = worst, 9 = best) taken on 5 Mar. 2010 in Riverside and Irvine, CA, on plots converted from tall fescue to warm-season turf using three different removal methods (no removal, scalping, or glyphosate). Values represent an average of three replications.

Species	Removal	Color (1–9 scale)		Quality (1–9 scale)	
		Riverside	Irvine	Riverside	Irvine
Hybrid bermudagrass	No removal	2.0 deA ^z	2.0 cdA	1.7 eA	2.0 cdA
	Scalping	1.7 efB	2.0 cdA	2.0 deA	2.0 cdA
	Glyphosate	5.0 aA	4.0 aB	5.0 aA	3.0 aB
Bermudagrass seeds	No removal	2.0 deA	2.0 cdA	2.0 deA	2.0 cdA
	Scalping	1.7 efB	2.0 cdA	1.7 eA	1.7 deA
	Glyphosate	4.7 aA	2.7 bcB	4.0 bA	2.3 bcB
Buffalograss	No removal	2.0 deA	2.0 cdA	2.0 deA	1.7 deB
	Scalping	2.0 deA	2.0 cdA	2.0 deA	2.0 cdA
	Glyphosate	2.7 cdA	2.7 cA	2.0 deA	2.0 cdA
Seashore paspalum plugs	No removal	2.0 deA	2.0 cdA	1.7 eA	1.7 deA
	Scalping	1.7 efB	2.0 cdA	2.0 deA	2.0 cdA
	Glyphosate	2.0 deB	2.7 bcA	2.0 deA	2.3 bcA
Seashore paspalum seeds	No removal	2.0 deA	2.0 cdA	2.0 deA	2.0 cdA
	Scalping	1.3 fA	1.3 fgA	1.3 fB	2.0 cdA
	Glyphosate	5.3 aA	3.0 bB	5.0 aA	2.0 cdB
St. augustinegrass	No removal	2.0 deA	1.0 gB	2.0 deA	1.0 fB
	Scalping	2.0 deA	1.8 gA	2.0 deA	2.0 cdA
	Glyphosate	3.0 cA	2.0 cdA	3.0 cA	1.0 fB
Hybrid zoysiagrass	No removal	2.1 deA	1.6 efB	2.1 deA	1.3 efB
	Scalping	1.7 efB	2.0 cdA	1.8 eA	2.0 cdA
	Glyphosate	3.3 bcA	2.0 cdA	3.0 cA	2.0 cdB

^zValues followed by the same lower case letter are not significantly different in a column via Fisher's protected least significant difference (LSD) at $P = 0.05$. Values followed by the same upper case letter are not significantly different in a row via Fisher's protected LSD at $P = 0.05$.

established faster than vegetatively propagated cultivars. Overall, these results suggest that eradication of existing turf followed by seeding bermudagrass or seashore paspalum will result in the best and easiest success in turf conversion for water savings in a Mediterranean climate.

Literature cited

- Brede, A.D. and J.M. Duich. 1986. Plant interaction among *Poa annua*, *Poa pratensis*, and *Lolium perenne* turfgrasses. *Agron. J.* 78:179–184.
- Busey, P. 2003. St. augustinegrass, *Stenotaphrum secundatum* (Walt.) Kuntze, p. 309–330. In: M.D. Casler and R.R. Duncan (eds.). *Biology, breeding, and genetics of turfgrasses*. Wiley, Hoboken, NJ.
- City of Albuquerque, NM. 2000. Water budgets and planting restrictions. § 6-1-1-8. In: Code of ordinances. City of Albuquerque, NM.
- Egley, G.H. and R.D. Williams. 1978. Glyphosate and paraquat effects on weed seed germination and seedling emergence. *Weed Sci.* 26:249–251.
- Fry, J. and B. Huang. 2004. *Applied turfgrass science and physiology*. Wiley, Hoboken, NJ.
- Fry, J., R. Taylor, B. Wolf, D. Stunz, and A. Zuk. 2007. Development of a strip seeder for converting cool-season turf to seeded bermudagrass. *HortTechnology* 17:363–367.
- Green, R.L. 2005. Trends in golf course water use and regulation in California. In: Reports on topical issues. 1 May 2013. <<http://agops.ucr.edu/turf/>>.
- Huang, B. and J. Fry. 1999. Turfgrass evapotranspiration. *Crop Production* 2: 317–333.
- Hurto, K.A. and A.J. Turgeon. 1978. Impact of thatch on residual activity of herbicides used in turfgrass renovation. 1977 Mtg. Weed Sci. Soc. Amer. p. 50. (Abstr.).
- Jellicorse, W.R., M.D. Richardson, J.H. McCalla, D.E. Karcher, A.J. Patton, and J.W. Boyd. 2012. Seeded bermudagrass establishment in an overseeded perennial ryegrass stand as affected by transition herbicide and seeding date. *Appl. Turfgrass Sci.* doi:10.1094/ATS-2012-0721-01-RS.
- Kaufman, J.E. 1978. Turfgrass renovation with glyphosate. 1977 Mtg. Weed Sci. Soc. Amer. p. 50. (Abstr.).
- Kenna, M.P. 2008. Turfgrass and the environment, p. 65–90. In: J.B. Beard and M.P. Kenna, (eds.). *Water quality and quantity issues for turfgrasses in urban landscapes*. Council Agr. Sci. Technol., Ames, IA.
- Kim, K.S. 1983. Comparative evapotranspiration rates of thirteen turfgrasses grown under both non-limiting soil moisture and progressive water stress conditions. Texas A&M Univ., College Station, MS Thesis.
- Kollenkark, J. and W.H. Daniel. 1978. Glyphosate and its effect on seed germination. 1977 Mtg. Weed Sci. Soc. Amer. p. 6. (Abstr.).
- Marshall, A.H. and R.E.L. Naylor. 1984. The effect of leachates from grass trash on establishment of ryegrass. *Ann. Appl. Biol.* 105:75–86.
- Metropolitan Water District of Southern California. 2013. Residential turf removal program. 1 May 2013. <<http://socalwatersmart.com/index.php/qualifyingproducts/turfremoval>>.
- Meyer, J.L., V.A. Gibeault, and V.B. Youngner. 1985. Irrigation of turfgrass below replacement of evapotranspiration as a means of water conservation: Determining crop coefficient of turfgrasses, p. 357–364. In: F. Lemaire (ed.). *Proc. 5th Intl. Turfgrass Res. Conf.*, Avignon, France, July 1985. INRA Publ., Versailles, France.
- Mittlesteadt, T.L., J.M. Goatley, S.D. Askew, K.L. Hensler, and W.L. Askew. 2009. Low-impact conversion of cool-season turf to ‘Patriot’ bermudagrass. *Intl. Turfgrass Soc. Res. J.* 11:1205–1212.
- Morris, K.N. 2002. National Turfgrass Evaluation Program. 1997 National Bermudagrass Test. NTEP No. 02–7. U.S. Dept. Agr., Beltsville, MD.
- Munshaw, G.C., D.W. Williams, A.J. Powell, Jr., and C.T. Dougherty. 1998. Growth and development of seeded versus vegetative bermudagrass varieties. *Annu. Mtg. Abstr. Amer. Soc. Agron., Crop Sci. Soc. Amer., Soil Sci. Soc. Amer.* p.136. (Abstr.).
- Patton, A.J., D.W. Williams, and Z.J. Reicher. 2004. Renovating golf course fairways with zoysiagrass seed. *HortScience* 39:1483–1486.
- Patton, A.J., M.D. Richardson, D.E. Karcher, J.W. Boyd, Z.J. Reicher, J.D. Fry, J.S. McElroy, and G.C. Munshaw. 2008. A guide to establishing seeded bermudagrass in the transition zone. *Appl. Turfgrass Sci.* doi:10.1094/ATS-2008-0122-01-MD.
- Patton, A.J., M.D. Richardson, D.E. Karcher, and J. Trappe. 2009. 2007 NTEP seashore paspalum trial—Year 1 and 2 results. *Arkansas Turfgrass Rpt., Arkansas Agr. Expt. Sta. Res. Serv.* 568:60–63.
- Qian, Y.L., J.D. Fry, and W.S. Upham. 1997. Rooting and drought avoidance of warm-season turfgrasses and tall fescue in Kansas. *Crop Sci.* 37:905–910.
- Richie, W.E., R.L. Green, G.J. Klein, and J.S. Hartin. 2002. Tall fescue performance influenced by irrigation scheduling, cultivar, and mowing height. *Crop Sci.* 42:2011–2017.
- Rimi, F., S. Macolino, B. Leinauer, and U. Ziliotto. 2011. Green up of seeded bermudagrass cultivars as influenced by spring scalping. *HortTechnology* 21:230–235.
- Schiavon, M., B. Leinauer, M. Serena, R. Sallenave, and B. Maier. 2012. Bermudagrass and seashore paspalum establishment from seed using differing irrigation methods and water qualities. *Agron. J.* 104:706–714.
- Shaver, B.R., M.D. Richardson, J.H. McCalla, D.E. Karcher, and P.J. Berger. 2006. Dormant seeding bermudagrass cultivars in a transition-zone environment. *Crop Sci.* 46:1787–1792.
- Sheffer, K.M., J.H. Dunn, and D.D. Minner. 1987. Summer drought responses and rooting depth of three cool-season turfgrasses. *HortScience* 22:296–297.
- State of California. 2009. Updated model water efficient landscape ordinance AB 1881. 1 May 2013. <<http://www.water.ca.gov/wateruseefficiency/landscapeordinance>>.
- Williams, D.W. and P.B. Burrus. 2004. Conversion of perennial ryegrass to bermudagrass using seeded cultivars, herbicides, and plant growth regulators. *HortScience* 39:398–402.
- Zuk, A. and J.D. Fry. 2005. Seeded zoysiagrass establishment in a perennial ryegrass sward. *Crop Sci.* 45:1521–1528.
- Zuk, A. and J.D. Fry. 2006. Inhibition of ‘Zenith’ zoysiagrass seedling emergence and growth of perennial ryegrass leaves and roots. *HortScience* 41:818–821.