Seed Coating and Seeding Rate Effects on Turfgrass Germination and Establishment

Bernd Leinauer^{1,3}, Matteo Serena¹, and Devesh Singh²

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SUMMARY. A field experiment was conducted at New Mexico State University to investigate the effect of seeding rates and ZEBA polymer [starch-g-poly (2-propenamide-co-propenoic acid) potassium salt] seed coating on the germination and establishment of warm- and cool-season grasses, and cool-season blends and mixtures. Grasses were established at recommended and reduced (50% of recommended) seeding rates with coated and uncoated seeds under two irrigation regimes (98% and 56% reference evapotranspiration). With the exception of 'Bengal' creeping bentgrass (*Agrostis stolonifera*), the polymer coating did not improve germination of the turfgrasses tested 22 days after seeding (DAS). However, at the end of the establishment period (92 DAS), plots established with 'Bengal', Dunes Mix [mixture of 'Hardtop' hard fescue (*Festuca longifolia*), 'Baron' kentucky bluegrass (*Poa pratensis*), 'Barok' sheep fescue (*Festuca ovina*)], 'Panama' bermudagrass (*Cynodon dactylon*), and Turf SenseTM [mixture of 'Baronie' kentucky bluegrass, 'Barlennium' perennial ryegrass (*Lolium perenne*), and 'Barcampisia' tufted hairgrass (*Deschampsia cespitosa*)] achieved greater coverage (based on visual estimations) when coated seed was used compared with uncoated seed. Establishment was greater for 'Bengal', Dunes Mix, 'Panama', Turf SenseTM, and Turf SaverTM [blend of 'Barlexas II', 'Barrington', and 'Labarinth' tall fescue (*Festuca arundinacea*)] when normal seeding rates were applied compared with reduced seeding rates. 'Barleria' crested hairgrass (*Koeleria macrantha*) plots did not establish, regardless of the treatments applied. Results showed that seed coating has the potential to improve establishment at recommended and reduced seeding rates and can compensate for less favorable conditions such as reduced irrigation, reduced seeding rate, or for a combination of both. At the end of the establishment period, not all grasses achieved coverage greater than 50%. Further research over a longer establishment period is needed to determine if coated seed can be beneficial in achieving full coverage.

Seeding is the most common establishment method used for turf areas (Christians, 1998). Seeding keeps establishment costs to a minimum (Burton, 1992) and is convenient because of the ease of transportation, storage, and spreading of seeds (Christians, 1998; Watschke and Schmidt, 1992). Seed coating was introduced by the vegetable industry in the late 1930s and early 1940s to increase seed size and

achieve seed uniformity (Kaufman, 1991; Roos and Moore, 1975). Seed coating has since evolved from simply changing seed size and shape to producing treated coatings to supply compounds that influence the microenvironment of each seed. Compounds can include fungicides, insecticides, herbicides, micro- and macronutrients, growth regulators, surfactants, and polymers, pesticides to protect from birds and rodents, and chemicals that stimulate or delay germination (Scott, 1989). The first published greenhouse study using coated turfgrass seed concluded that adhesives used to coat seed with

limestone did not negatively impact kentucky bluegrass and tall fescue seedlings (Hathcock et al., 1984a). However, since then, the use of coated and treated seed in turfgrass establishment has given conflicting results. In a concurrent field study, Hathcock et al. (1984b) found that limestone in combination with various fertilizers as coating material improved germination or killed tall fescue or kentucky bluegrass seedlings, depending on the type of fertilizer coating. Berdahl and Barker (1980) tested five different water-adsorbent coatings on seed of russian wildrye (*Elymus junceus*) and found no effect on seed emergence over a wide range of soil matric potentials. Bruneau et al. (1989) investigated fertilizer-coated cool-season turf seed and found reduced germination in complete fertilizer-coated grass seed compared with grasses seeded with raw seed. The authors concluded that coated seed could not be recommended unless seeding rates were increased. However, Greipsson (1999) documented improved kentucky bluegrass establishment when seed coated with diatomaceous earth and cytokinins was used compared with uncoated seed or seed coated with diatomaceous earth only. To prevent seedling diseases, coatings treated with fungicides were introduced in late 1980s and early 1990s (Baldwin, 1993; Hummel, 1991). Hummel (1991) investigated seed coatings that included starter fertilizer and the fungicide metalaxyl at full and half seeding rates of creeping bentgrass and perennial ryegrass. He concluded that the coating increased establishment but could not compensate for the reduced seed density at half seeding rate. Conditions during the investigation did not allow for the evaluation of the fungicide treatment (Hummel, 1991). Research conducted by Newell (1997) and Newell et al. (1999) found increased establishment in kentucky bluegrass,

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¹Department of Plant and Environmental Sciences, New Mexico State University, N230 Skeen Hall, Las Cruces, NM, 88003

²Barenbrug USA, West Coast Research Center, 36030 Tennessee Road, Albany, OR 97322

³Corresponding author. E-mail: leinauer@nmsu.edu.

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
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
305.1517	oz./ft ²	g·m ⁻²	0.0033
6.8948	psi	kPa	0.1450

perennial ryegrass, red fescue (*Festuca rubra*), and two seed mixtures when fungicide-coated seed was used and compared with controls. Most recently, Layton et al. (2007) investigated the effects of coating on warm-season seeded bermudagrass germination at six temperatures regimes. Seed coating of all five bermudagrasses did not increase germination compared with uncoated seed when germination was averaged across temperatures.

Since the introduction of seed coating, numerous coating materials have been suggested and tested, many of which are proprietary and unique to each seed company. Most recently, a new cornstarch coating by the name of ZEBa (Absorbent Technologies, Beaverton, OR) has been released and applied to warm- and cool-season turfgrass seeds (Arends, 2007). The coating consists of a polymer that exhibits water-retention capabilities of 400 times of its own weight (Absorbent Technologies, 2006; Arends, 2007). Currently, information is lacking on the effect of starch coating on germination and establishment of turfgrasses. Two studies were conducted at New Mexico State University, Las Cruces (U.S. Department of Agriculture Plant Hardiness Zone 8) to investigate the effect of ZEBa seed coating and seeding rates on the germination and establishment of cool-season turfgrasses, cool-season mixtures and blends, and bermudagrass when seeded in fall.

Material and methods

Field experiments were conducted at New Mexico State University from Sept. to Dec. 2006 to investigate the effect of seeding rates and ZEBa polymer seed coating on the germination and establishment of cool-season turfgrasses, cool-season blends and mixtures, and bermudagrass. The experimental design was a completely randomized block with turfgrasses, coating, and seeding rate as the main plot treatments (replicated four times) and day after seeding (DAS) as subplot treatments. The experiment was repeated at high irrigation [98% reference evapotranspiration (ET_o)] and at moderate irrigation (56% ET_o). Irrigation was applied through a subsurface drip system (DL2000TM; Toro, Riverside, CA) operated at 30 psi and installed at

a soil depth of 10 cm. Drip lines were placed 30 cm apart from each other and pressure compensating emitters delivered water at a rate of 2 L·h⁻¹. Subsurface drip irrigation was chosen because of the site's wind exposure that historically resulted in poor irrigation coverage from sprinkler systems. Irrigation amounts were calculated every Monday morning based on the previous week's cumulative ET_o (Doorenbos and Pruitt, 1977). The 98% ET_o treatment received a daily equivalent of 14% of the total weekly ET_o , and the 56% ET_o treatment received 14% of the previous week's ET_o every Monday, Wednesday, Friday, and Saturday. Visual inspection during the establishment period ensured that wetting fronts from drip irrigation lines reached the soil surface and moistened the soil uniformly. The soil at the site consisted of a sandy skeletal mixed thermic Typic Torriorthent, a sandy entisol typical for arid regions.

Grasses were seeded on 11 Sept. 2006 and a starter fertilizer (15N–6.5P–12.5K) was applied twice at a rate of 5 g·m⁻² nitrogen during the course of the study. Plot size was 1 × 1 m. Grasses included 'Panama' bermudagrass, 'Bengal' creeping bentgrass, and 'Barleria' crested hairgrass. Furthermore, two cool-season blends, Turf BlueTM (kentucky bluegrass; Barenbrug USA, Tangent, OR) and Turf SaverTM (tall fescue; Barenbrug USA), and two cool-season mixtures, Dunes Mix and Turf SenseTM (2) (Barenbrug USA) were tested. The mixtures included 'Hardtop' hard fescue, 'Baron' kentucky bluegrass, and 'Barok' sheep fescue, and 'Baronnie' kentucky bluegrass, 'Barlennium' perennial ryegrass, and 'Barcampsia' tufted hairgrass, respectively. Grasses, blends, and mixtures were seeded at recommended or reduced (50% of recommended) seeding rates, and seeding rates for coated grasses were increased to match seed number per plot of uncoated seed (Table 1).

Plots were assessed visually for seed germination on 21 Sept. 2006 (10 DAS) and on 3 Oct. (22 DAS) and for turfgrass coverage on 26 Oct. (45 DAS), 7 Nov. (57 DAS), 18 Nov. (68 DAS), 28 Nov. (78 DAS), and 12 Dec. (92 DAS). Germination ratings were taken across the entire plot on a scale of 0 to 3 with 0 = no germination and 3 = visible germination. A

rating system that used a visual assessment of the entire plot rather than a seedling count was deemed appropriate because germination varied greatly among grasses and we were unable to choose a day that allowed for adequate seedling counts for all entries. When slower germinating grasses finally reached a countable mass, plots with faster germinating grasses had already reached a plant density that could no longer be counted. Turfgrass coverage was estimated using visual ratings that described the percentage coverage of the turfgrass' plots. A scatter plot of coverage versus DAS suggested a non-linear relationship between the two variables. A sigmoidal association was identified to best describe establishment of the turf plots (GraphPad Prism 5.0 for Windows; GraphPad Software, La Jolla, CA). With this model, establishment begins at zero, increases first slowly, then rapidly, and progresses asymptotically toward a maximum cover, also called top plateau (Fig. 1). The model was subsequently used to calculate maximum cover and DAS to reach 50% cover for each treatment. Karcher et al. (2005a, 2005b) used 50% coverage as a benchmark for turfgrass recovery from divot injury and this value was deemed appropriate to be applied to our study. Germination data, maximum cover, and DAS values were subjected to analysis of variance using SAS Proc Mixed (version 9.2; SAS Institute, Cary, NC) followed by multiple comparisons of means using Fisher's protected least significant difference test at the 0.05 *P* level.

Results and discussion

GERMINATION. The analysis of turfgrass germination revealed significant four-way interactions among irrigation, species, seeding rate, and DAS ($P = 0.007$), and significant two-way interaction between species and coating ($P = 0.041$). All other four- and all three-way interactions were not significant ($P > 0.05$). Therefore, germination means were pooled first over coating and are presented separately for each species, seeding rate, coating, and DAS for each irrigation treatment (Table 2). Second, germination means were pooled over irrigation, seeding rate, and DAS and are presented separately for each species and coating treatment (Table 3).

Table 1. Turfgrass mixtures, blends, species, and varieties, and corresponding recommended seeding rates of all entries included in the study of seed coating and seeding rate effects on germination and stand establishment.

Mixture	Blend	Species	Variety	Recommended seeding rate: uncoated ^z	
				(g·m ⁻²)	(seeds/m ²)
Dunes Mix	Turf Blue TM ^x	Bermudagrass	Panama	10	37,145
		Creeping bentgrass	Bengal	5	81,720
		Crested hairgrass	Barleria	10	34,050
		Kentucky bluegrass	Bariris (25%) ^y	10	20,954
			Barrister (40%)		
	Turf Saver TM ^x		Baron (20%)		
			Barimpala (15%)		
		Tall fescue	Barlexas II (30%)	30	10,753
			Barrington (30%)		
			Labarinth (40%)		
Turf Sense TM ^x		Hard fescue	Hardtop (70%)	25	29,609
		Kentucky bluegrass	Baron (5%)		
		Sheep fescue	Barok (25%)		
		Kentucky bluegrass	Baronie (10%)	10	23,349
		Perennial ryegrass	Barlennium (20%)		
		Tufted hairgrass	Barcampsia (70%)		

^z1 g·m⁻² = 0.0033 oz/ft², 1 seed/m² = 0.0929 seed/ft².

^yPercentage value listed next to variety name indicates the percentage by weight in mixture or blend.

^xBarenbrug USA, Tangent, OR.

Fig. 1. Percentage turf cover under high [98% reference evapotranspiration (ET_o)] and moderate (56% ET_o) irrigation as affected by days after seeding (DAS). Data were pooled over grasses ‘Barleria’ crested hairgrass, ‘Bengal’ creeping bentgrass, ‘Panama’ bermudagrass, Dunes Mix (mixture of ‘Hardtop’ hard fescue, ‘Baron’ kentucky bluegrass, and ‘Barok’ sheep fescue), Turf SenseTM (Barenbrug USA, Tangent, OR; mixture of ‘Baronie’ kentucky bluegrass, ‘Barlennium’ perennial ryegrass, and ‘Barcampsia’ tufted hairgrass), Turf BlueTM (Barenbrug USA; blend of ‘Bariris’, ‘Barrister’, ‘Baron’, and ‘Barimpala’ kentucky bluegrass), and Turf SaverTM (Barenbrug USA; blend of ‘Barlexas II’, ‘Barrington’, and ‘Labarinth’ tall fescue), seed treatment (coated and uncoated), and seeding rates [normal (according to rates recommended for uncoated seed by manufacturer) and 50% of normal rate]. Data points represent an average of 112 replicates. Error bar at the top plateau indicates a significant difference between the high ET_o and the moderate ET_o irrigation treatment via Fisher’s protected least significant difference at $\alpha = 0.05$.

‘Barleria’ and ‘Panama’ showed lowest germination among all tested grasses. Seeding rate and irrigation regime had no effect on their germination (Table 2). Normal seeding rates of ‘Bengal’ and Turf SaverTM resulted in highest germination rates under high and moderate irrigation (Table

2). Turf SaverTM also had the highest germination rates at reduced seeding rates on 10 and 22 DAS (Table 2). With the exception of Turf SenseTM at high irrigation, all grasses showed lower germination at reduced seeding rates compared with normal seeding rates (Table 2). With the exception of

‘Bengal’, coating did not improve germination of the turfgrasses tested (Table 3).

Whether seed coating increases germination or not appears to be dependent on the type of coating. Fertilizer coating as used in previous studies (Bruneau et al., 1989; Hathcock et al., 1984b) improved or reduced germination. This can be explained by a high nutrient availability to the seedling, which impacts germination positively, or, due to a relatively high salt concentration in the coating surrounding the endosperm, negatively. Corn starch coating, however, which has little to no nutritional value, affects only seed water availability. Based on our findings, with the exception of ‘Bengal’, increased moisture alone was not sufficient to impact seed germination. Our findings concur with those of Berdahl and Barker (1980) who found no increased emergence of starch-coated russian wildrye seed compared with the uncoated control over several moisture ranges.

ESTABLISHMENT. The rate of establishment of the different turfgrasses was best described by the sigmoidal curve, yielding coefficients of determination (R^2) values ranging from 0.83 to 1.00. Analysis of variance of maximum coverage data revealed significant species by moisture ($P = 0.01$) and species by seeding rate ($P = 0.008$) interactions and

Table 2. Turfgrass germination ratings for high [98% reference evapotranspiration (ET_o)] and moderate (56% ET_o) irrigation treatments at normal (recommended; uncoated) and reduced seeding rates (50% of normal) and at 10 and 22 d after seeding (DAS) when data were pooled over seed treatments (coating).

Mixture	Blend	Variety	Normal seeding rate ^z		Reduced seeding rate	
			10 DAS	22 DAS	10 DAS	22 DAS
			Germination rating (0 to 3 scale) ^y			
Dunes Mix ^w	Turf Blue ^{TMv} Turf Saver ^{TMu}	Barleria	<i>High ET_o</i>			
			0.0 c ^x	0.2 d	0.0 c	0.0 c
			2.0 a	2.5 ab	0.8 b	1.0 b
		Panama	2.0 a	2.2 b	1.0 b	1.0 b
			0.0 c	0.2 d	0.0 c	0.0 c
			1.2 b	1.3 c	1.0 b	1.0 b
			2.5 a	2.8 a	1.7 a	2.3 a
Turf Sense ^{TMt}	0.9 b	1.1 c	1.0 b	1.0 b		
	Dunes Mix	Turf Blue TM Turf Saver TM	Barleria	<i>Moderate ET_o</i>		
0.0 d				0.0 e	0.0 d	0.0 d
2.0 a				2.3 b	0.5 c	0.5 c
Panama			1.3 b	1.7 c	1.0 b	1.0 b
			0.0 d	0.0 e	0.0 d	0.0 d
			0.3 d	0.7 d	0.2 cd	0.2 cd
			1.8 a	3.0 a	1.8 a	2.0 a
Turf Sense TM	0.8 c	1.0 d	1.0 b	1.0 b		

^zThe following normal seeding rates (according to rates recommended for uncoated seed by manufacturer) were applied: 'Barleria' crested hairgrass 10 g·m⁻², 'Bengal' creeping bentgrass 5 g·m⁻², Dunes Mix 25 g·m⁻², 'Panama' bermudagrass 10 g·m⁻², Turf BlueTM 10 g·m⁻², Turf SaverTM 30 g·m⁻², and Turf SenseTM 10 g·m⁻² (1 g·m⁻² = 0.0033 oz/ft²).

^y0 = no germination and 3 = visible germination across the entire plot.

^xValues in columns (separately for each irrigation regime) followed by the same letter are not significantly different from one another via Fisher's protected least significant difference at $\alpha = 0.05$.

^wMixture of 'Hardtop' hard fescue, 'Baron' kentucky bluegrass, and 'Barok' sheep fescue.

^vBarenbrug USA, Tangent, OR; blend of 'Bariris', 'Barrister', 'Baron', and 'Barimpala' kentucky bluegrass.

^uBarenbrug USA; blend of 'Barlexas II', 'Barrington', and 'Labarinth' tall fescue.

^tBarenbrug USA; mixture of 'Baronie' kentucky bluegrass, 'Barlennium' perennial ryegrass, and 'Barcampia' tufted hairgrass.

Table 3. Turfgrass germination ratings for coated and uncoated turfgrass seed when data were pooled over irrigation treatments {high [98% reference evapotranspiration (ET_o)] and moderate (56% ET_o)}, seeding rates [normal (recommended; uncoated^z) and reduced (50% of normal)], and days after seeding (10 and 22 d).

Mixture	Blend	Variety	Seed treatment	
			Coated	Uncoated
			Germination rating (0–3 scale) ^y	
Dunes Mix ^v	Turf Blue ^{TM^u} Turf Saver ^{TM^t}	Barleria	0.0 d ^s	0.0 e
		Bengal	1.7 bA ^w	1.2 bcB
		Panama	1.5 b	1.3 b
			0.0 d	0.0 e
			0.8 c	0.7 d
Turf Sense ^{TM^s}			2.2 a	2.3 a
			0.9 c	1.0 c

^zThe following normal seeding rates (according to rates recommended for uncoated seed by manufacturer) were applied: 'Barleria' crested hairgrass 10 g·m⁻², 'Bengal' creeping bentgrass 5 g·m⁻², Dunes Mix 25 g·m⁻², 'Panama' bermudagrass 10 g·m⁻², Turf BlueTM 10 g·m⁻², Turf SaverTM 30 g·m⁻², and Turf SenseTM 10 g·m⁻² (1 g·m⁻² = 0.0033 oz/ft²).

^y0 = no germination and 3 = visible germination across the entire plot.

^xValues in columns followed by the same lower case letter are not significantly different from one another via Fisher's protected least significant difference (LSD) at $\alpha = 0.05$.

^wValues within one row followed by different upper case letters are significantly different from one another via LSD at $\alpha = 0.05$.

^vMixture of 'Hardtop' hard fescue, 'Baron' kentucky bluegrass, and 'Barok' sheep fescue.

^uBarenbrug USA, Tangent, OR; blend of 'Bariris', 'Barrister', 'Baron', and 'Barimpala' kentucky bluegrass.

^tBarenbrug USA; blend of 'Barlexas II', 'Barrington', and 'Labarinth' tall fescue.

^sBarenbrug USA; mixture of 'Baronie' kentucky bluegrass, 'Barlennium' perennial ryegrass, and 'Barcampia' tufted hairgrass.

a significant moisture effect ($P < 0.0001$). All other two-, three-, and four-way interactions were not significant ($P > 0.05$). When data were

pooled over all species, seeding rates, and coating treatments, plots established under moderate irrigation achieved lower maximum coverage

(36%) compared with plots under high irrigation (45%) (Fig. 1).

Plots established with coated seed of 'Bengal', Dunes Mix, 'Panama', and Turf SenseTM achieved greater coverage than those established with uncoated seed. Coating did not affect coverage of 'Barleria', Turf BlueTM, or Turf SaverTM (Table 4). Seeding rate affected coverage on all plots except those of 'Barleria' (Table 4). Applying recommended seeding rates of 'Bengal', Dunes Mix, 'Panama', Turf BlueTM, Turf SaverTM, and Turf SenseTM resulted in significantly greater establishment and coverage than under reduced seeding rate. 'Barleria'-seeded plots exhibited poor coverage, regardless of the treatments applied. Crested hairgrass has shown a history of germinating and establishing poorly because of seed dormancy issues (C. Arends, personal communication). Conditions necessary to break seed dormancy and achieve satisfactory establishment in this species have yet to be determined.

Several treatments included in this study did not reach 50% coverage by the end of the 3-month investigative period. Therefore, data were

Table 4. Maximum turfgrass coverage (based on sigmoidal model estimates) for coated versus uncoated turfgrass species {data pooled over high [98% reference evapotranspiration (ET_o)] and moderate (56% ET_o) irrigation and seeding rates [normal (recommended)^z and reduced (50% of normal rate)] and for species established at normal and reduced seeding rates [data pooled over high ET_o and moderate ET_o irrigation and over coating (coated and uncoated) treatments].

Mixture	Blend	Variety	Seed treatment		Seeding rate	
			Coated	Uncoated	Normal	Reduced
			Maximum coverage (%)			
Dunes Mix ^w	Turf Blue ^{TMv} Turf Saver ^{TMu}	Barleria	15 f ^y	14 d	17 f	12 d
		Bengal	64 aA ^x	54 aB	70 aA	48 aB
			57 bA	47 bB	61 bA	43 abB
		Panama	34 eA	15 dB	31 eA	17 dB
			48 c	43 b	51 cA	41 bB
Turf Sense ^{TMt}			54 bc	47 b	56 bcA	45 abB
			41 dA	31 cB	42 dA	30 cB

^zThe following normal seeding rates (according to rates recommended for uncoated seed by manufacturer) were applied: 'Barleria' crested hairgrass 10 g·m⁻², 'Bengal' creeping bentgrass 5 g·m⁻², Dunes Mix 25 g·m⁻², 'Panama' bermudagrass 10 g·m⁻², Turf BlueTM 10 g·m⁻², Turf SaverTM 30 g·m⁻², and Turf SenseTM 10 g·m⁻² (1 g·m⁻² = 0.0033 oz./ft²).

^yValues in columns followed by the same lower case letter are not significantly different from one another via Fisher's protected least significant difference (LSD) at $\alpha = 0.05$.

^xValues within one row (which consists of coated versus uncoated for seed treatment and normal versus reduced for seeding rate) followed by different upper case letters are significantly different from one another via LSD at $\alpha = 0.05$.

^wMixture of 'Hardtop' hard fescue, 'Baron' kentucky bluegrass, and 'Barok' sheep fescue.

^vBarenbrug USA, Tangent, OR; blend of 'Bariris', 'Barrister', 'Baron', and 'Barimpala' kentucky bluegrass.

^uBarenbrug USA, Tangent, OR; blend of 'Barlexas II', 'Barrington', and 'Labarinth' tall fescue.

^tBarenbrug USA, Tangent, OR; mixture of 'Baronic' kentucky bluegrass, 'Barlennium' perennial ryegrass, and 'Barcampisia' tufted hairgrass.

analyzed separately for each irrigation treatment, coating treatment, and seeding rate. Table 5 lists DAS to reach 50% coverage separately for each species, seeding rate, irrigation, and coating. Most grasses achieved 50% coverage when coated seed was used at a normal seeding rate and high irrigation was applied. Turf SenseTM was slowest to reach 50% compared with other grasses. 'Bengal' creeping bentgrass reached the 50% plateau with all treatment combinations except when uncoated seed was used at a reduced seeding rate under moderate irrigation. 'Bengal', Dunes Mix, and Turf SaverTM reached 50% coverage using coated seed at a reduced seeding rate under moderate irrigation. Days needed to reach 50% coverage differed among cool-season grasses only under high irrigation at normal seeding rates. Turf SenseTM was slowest to reach 50% when coated seed was used and Turf SaverTM was slowest when uncoated seed was used. Turf SenseTM did not reach 50% coverage when uncoated seed was used (Table 5). As a group, cool-season grasses established best (as indicated by the number of grasses that reached 50% cover) when normal seeding rate and coated seed at high irrigation was applied.

Progressively fewer cool-season grasses reached 50% coverage as the number of suboptimum treatments (uncoated seed, reduced seeding rate, and moderate irrigation) increased (Table 5). Only 'Bengal' achieved 50% coverage at a reduced seeding rate using uncoated seed but high irrigation, and only Turf SaverTM reached 50% coverage at 109 DAS under the least favorable conditions (reduced seeding rate, uncoated seed, and moderate irrigation) (Table 5).

Our results indicate that seed coating can reduce the effect of less favorable conditions such as moderate irrigation, reduced seeding rate, or for a combination of both. 'Bengal', Dunes Mix, Turf BlueTM, and Turf SaverTM all achieved 50% coverage under high irrigation at normal seeding rate with uncoated seed and also at reduced seeding rate with coated seed. 'Bengal', Dunes Mix, and Turf SaverTM also reached 50% coverage under moderate irrigation at a reduced seeding rate with coated seed compared with normal seeding rate and uncoated seed. Furthermore, 'Bengal', Dunes Mix, and Turf SaverTM achieved 50% coverage under moderate irrigation when coated seed was used and a reduced seeding rate was applied (Table 5).

'Barleria' crested hairgrass and 'Panama' bermudagrass did not reach 50% even under the most favorable conditions. 'Panama' reached 50% coverage only under moderate irrigation when coated seed was applied at a normal seeding rate (Table 5). Delayed or poor establishment for 'Panama' can be explained by the fall seeding, when soil temperatures were not high enough for warm-season grasses to achieve active growth. Moderately irrigated root zones may have been warmer than highly irrigated root zones and subsequently promoted a more favorable soil environment for bermudagrass establishment. 'Barleria' has a documented history of establishing poorly because of lack of breaking seed dormancy (C. Arends, personal communication).

Our results indicate that higher seeding rates improved germination while ZEB seed coating only had an effect on germination for 'Bengal' creeping bentgrass under reduced irrigation. However, seed coating had a significant effect on turfgrass establishment. At the end of the establishment period, four of the six cool-season grasses established better when coated seed was applied compared with uncoated seed. These results confirm those of Greipsson (1999) who also found increased establishment when seed coating was applied. At high irrigation and reduced seeding rate, four of the six cool-season grasses tested reached 50% coverage with coated seed compared with only one species when uncoated seed was used. Our results differ from those of Hummel (1991) who concluded that coating could not compensate for reducing the seeding rate by half. These differences can be explained by the different coating material (starter fertilizer and fungicide) that Hummel (1991) used in his study compared with the starch coating in our study. While starter fertilizer and fungicide treatment have no effect on moisture retention of the seed, the starch coating used in our study may have increased water availability to the seed, which consequently increased establishment rate.

Grasses did not fully establish by early Jan. 2007 because temperatures dropped below freezing and grasses turned dormant. Hall (1980) reported reduced root development and subsequent damage due to desiccation in

Table 5. Days after seeding to reach 50% coverage (based on sigmoidal model estimates) for coated versus uncoated turfgrass species under high [98% reference evapotranspiration (ET_o)] and moderate irrigation (56% ET_o) and at normal (recommended: uncoated^a) and reduced (50% of normal rate) seeding rates.

Mixture	Blend	Variety	High ET _o irrigation		Moderate ET _o irrigation	
			Coated	Uncoated	Coated	Uncoated
			Time after seeding to reach 50% coverage (d)			
Normal seeding rate						
Dunes Mix [*]	Turf Blue ^{TM^w} Turf Saver ^{TM^v}	Barleria	dnr	dnr	dnr	dnr
		Bengal	53 b ^y	56 b	55 b	64
			53 b	61 b	54 b	59
		Panama	dnr	dnr	103 a	dnr
			61 b	59 b	69 ab	59
Turf Sense ^{TM^u}			59 b	66 a	73 ab	57
			84 a	dnr	dnr	dnr
Reduced seeding rate						
Dunes Mix	Turf Blue TM Turf Saver TM	Barleria	dnr	dnr	dnr	dnr
		Bengal	60	68	71	dnr
			57	dnr	53	dnr
		Panama	dnr	dnr	dnr	dnr
			76	dnr	dnr	dnr
Turf Sense TM			74	dnr	53	109
			dnr	dnr	dnr	dnr

^aThe following normal seeding rates (according to rates recommended for uncoated seed by manufacturer) were applied: 'Barleria' crested hairgrass 10 g·m⁻², 'Bengal' creeping bentgrass 5 g·m⁻², Dunes Mix 25 g·m⁻², 'Panama' bermudagrass 10 g·m⁻², Turf BlueTM 10 g·m⁻², Turf SaverTM 30 g·m⁻², and Turf SenseTM 10 g·m⁻² (1 g·m⁻² = 0.0033 oz/ft²).

^yValues in columns followed by the same letter (separate for each seeding rate) are not significantly different from one another (Fisher's protected least significant difference, $\alpha = 0.05$).

^xMixture of 'Hardtop' hard fescue, 'Baron' kentucky bluegrass, and 'Barok' sheep fescue.

^wBarenbrug USA, Tangent, OR; blend of 'Bariris', 'Barrister', 'Baron', and 'Barimpala' kentucky bluegrass.

^vBarenbrug USA, Tangent, OR; blend of 'Barlexas II', 'Barrington', and 'Labarinth' tall fescue.

^uBarenbrug USA, Tangent, OR; Mixture of 'Baronie' kentucky bluegrass, 'Barlennium' perennial ryegrass, and 'Barcampia' tufted hairgrass.

dnr: did not reach 50% coverage.

cool-season grasses that were established in the fall and went into dormancy prematurely. None of the treatments in this study reached full coverage by the end of the research period; however, coated grasses showed greater coverage and consequently greater maturity than uncoated grasses and would be less likely to be affected by desiccation and winter-kill. Further research over a longer establishment period is necessary to investigate if seed coating not only improves establishment to 50% coverage and compensates for a reduced seeding rate, but also to determine if establishing turf areas with coated seed can lead to irrigation water savings when full coverage needs to be achieved. In addition, research is needed to investigate whether coating increases the establishment of warm-season grasses when seeded at higher soil temperatures.

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