Research Reports

Cover Technology Influences Warm-season Grass Establishment from Seed

Aaron J. Patton[1], Jon M. Trappe, and Michael D. Richardson

ADDITIONAL INDEX WORDS. **blanket, mulch, erosion, bermudagrass, buffalograss, centipedegrass, seashore paspalum, zoysiagrass, *Cynodon dactylon*, *Buchloe dactyloides*, *Eremochloa ophiuroides*, *Paspalum vaginatum*, *Zoysia japonica***

SUMMARY. **Covers, mulches, and erosion-control blankets are often used to establish turf. There are reports of various effects of seed cover technology on the germination and establishment of warm-season grasses. The objective of this study was to determine how diverse cover technologies influence the establishment of bermudagrass (*Cynodon dactylon*), buffalograss (*Buchloe dactyloides*), centipedegrass (*Eremochloa ophiuroides*), seashore paspalum (*Paspalum vaginatum*), and zoysiagrass (*Zoysia japonica*) from seed. Plots were seeded in June 2007 or July 2008 with the various turfgrass species and covered with cover technologies, including Curlex, Deluxe, and Futerra products, jute, Poly Jute, polypropylene, straw, straw blanket, Thermal blanket, and the control. Establishment was reduced in straw- and polyethylene-covered plots due to decreased photosythentically active radiation penetration or excessive temperature build-up, respectively. Overall, Deluxe and Futerra products, jute, and Poly Jute allowed for the highest establishment of these seeded warm-season grasses.**

Covers, mulches, and erosion-control blankets are often used to establish turf. These technologies can be used to modify soil temperature (Barkley et al., 1965; Portz et al., 1993) and retain soil moisture (Dudeck et al., 1970; McGinnies, 1960) to increase germination (McGinnies, 1960) and establishment rates (Portz et al., 1993), as well as to reduce erosion (Krenitsky et al., 1998). Cover technology has been well-documented to influence the establishment of cool-season swards (Beard, 1966; Dudeck et al., 1970), but less is known about the establishment of warm-season grasses using various cover technologies.

The technologies used to establish turf are commonly referred to as mulches and/or erosion-control blankets (Lancaster and Austin, 2003), although germination covers or frost protection blankets are also used. Many of these blankets are designed for long-term soil stabilization (Lancaster and Austin, 2003). However, not all products used to establish turf are designed to reduce erosion, and a wide array of materials and constructions types are used to develop these diverse cover technologies.

Yu and Yeam (1967) first reported that the percentage of germination of zoysiagrass seed could be doubled by covering seeds with a polyethylene film, and Portz et al. (1993) found that clear polyethylene covers placed over the seedbed for 7 or 14 d after seeding increased zoysiagrass germination and coverage in Illinois and Maryland. Raymer et al. (2005) found that a combination mat/plastic cover was useful for establishing seashore paspalum from seed. Although soil surface temperatures rose as high as 56 °C under polyethylene covers, Portz et al. (1993) found little inhibition with zoysiagrass germination until soil temperatures exceeded 60 °C. However, Maki et al. (1989) reported that zoysiagrass seedlings can be killed or injured at temperatures above 50 °C under polyethylene. These studies indicate that polyethylene covers can be used to increase germination and early establishment if removed no later than 14 d after seeding or before excessive temperature build-up.

Other materials tested such as straw (80 lb/1000 ft^2) did not enhance zoysiagrass establishment from seed because they exclude light and reduce soil temperature (Portz et al., 1993). Organic fiber mats increased carpetgrass (*Axonopus affinis*) and zoysiagrass establishment when used in nonirrigated areas, likely due to

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
0.0929	ft^2	m^2	10.7639
2.54	inch(es)	cm	0.3937
0.4536	lb	kg	2.2046
48.8243	lb/1000 ft^2	kg·ha^{-1}	0.0205
1.1209	lb/acre	kg·ha^{-1}	0.8922
0.0254	mil	mm	39.3701
33.9057	oz/yard^2	g·m^{-2}	0.0295
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

Department of Horticulture, University of Arkansas, PTSC 316, 1 University of Arkansas, Fayetteville, AR 72701

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[1]Corresponding author. E-mail: ajpatton@uark.edu.

increased soil moisture retention, but did not increase establishment compared with control plots when irrigated (Hensler et al., 2001). Porous germination blankets made from spun-bound polyester can be used to establish bermudagrass and zoysiagrass (Patton et al., 2004), but these covers did not improve the establishment of zoysiagrass compared with polyethylene (Portz et al., 1993).

Previous research on the establishment of zoysiagrass and seashore paspalum from seed showed different effects from cover technologies, but no single study compared these cover technologies to one another. Additionally, very little information is available on the optimum cover technologies to use when planting bermudagrass, buffalograss, and centipedegrass from seed. The objective of this study was to determine how diverse cover technologies influence the establishment of five seeded warm-season grasses.

Materials and methods

A field study was conducted at the Arkansas Agricultural Research and Extension Center, Fayetteville, AR (lat. 36°06′N, long. 94°10′W, 1250 ft). The soil at the site was a Captina silt loam (fine-silty mixed mesic Typic Fragiudalt) with an average pH 5.5, 44 lb/acre phosphorus (P), 164 lb/acre potassium (K) in 2007 and pH 6.5, 82 lb/acre P, 80 lb/acre K in 2008 at the two separate planting locations as indicated by a soil test using the Mehlich 3 soil extraction. Experiments were seeded 9 June 2007 and 1 July 2008 with 'Riviera' bermudagrass at a rate of 49 $kg \cdot ha^{-1}$ pure live seed (PLS), 'Zenith' zoysiagrass at a rate of 98 $kg \cdot ha^{-1}$ PLS, 'Sea Spray' seashore paspalum at a rate of 49 $kg \cdot ha^{-1}$ PLS, 'TifBlair' centipedegrass at a rate of 24 $kg \cdot ha^{-1}$ PLS, and 'Bowie' buffalograss at a rate of 390 $kg \cdot ha^{-1}$ PLS in areas that were fumigated with methyl bromide at 732 $kg \cdot ha^{-1}$ ≈1 year before planting. Fumigation provided a relatively weed-free site on which turfgrass establishment could be closely monitored. Weed germination was minimal in the plot area, and those weeds were mechanically removed to reduce interference with data collection. The experimental area was tilled and raked immediately before seeding and lightly raked after seeding to improve seed-to-soil contact.

After seeding, plots were covered with various cover technologies (Table 1) as well as with a noncovered control. Plots were irrigated as needed after covers were applied to maintain a moist seedbed for 28 d after seeding (DAP) based upon the frequency of natural rainfall. Rainfall was frequent during both years following planting, and supplemental irrigation was needed and applied only on a few occasions to maintain a moist seedbed in covered and control plots. All covers were porous and allowed water (rain or irrigation) to penetrate from above, except for the polyethylene treatments. Polyethylene plots remained moist at all times, as noted by the condensation under the blankets, due to the ability to trap existing soil moisture (before planting) as well as from surrounding areas through cohesion and adhesion. Temporary covers (Table 1) were removed 14 DAP based on conclusions from previous work by Portz et al. (1993). Experimental design was a 5 × 11 factorial with five species and 11 cover treatments. Plots were arranged as a split block with three replications with an individual plot size of 4 × 6 ft. Both cover technology and species were applied as strips. Plots were fertilized 14 DAP and again 42 DAP at 49 lb/1000 ft^2 nitrogen (N) with urea (46N–0P–0K) and were mown at 1.5 inch as needed.

Turfgrass coverage was determined by visual estimates until 54

Table 1. Cover technologies tested at Fayetteville, AR, in 2007 and 2008 for the establishment of warm-season grasses from seed.

Cover technology[z]	Cover construction[y]	ECTC category[x]	Cover type
Clear polyethylene cover, 4 mil (local source)	Polyethylene	NA	Temporary
Curlex® natural aspen (American Excelsior, Arlington, TX)	Curled excelsior aspen wood fiber mat	ECB	Permanent
Deluxe (crop protection fabric, 0.5 oz/yard²; Dewitt Co., Sikeston, MO)	Spun-bound polypropylene fabric	NA	Temporary
Futerra® F4 Netless™, natural color (Profile Products, Buffalo Grove, IL)	Thermally Refined® wood	ECB	Permanent
Futerra®, natural color (Profile Products)	Thermally Refined® wood and degradable man-made fibers	ECB	Permanent
Jute erosion control mat (mesh fabric; local source)	Jute fiber mesh	ECB	Permanent
Poly Jute Netting (Dewitt Co.)	Polypropylene mesh	ECB	Permanent
Straw at 80 lb/1000 ft² (local source; Portz et al., 1993)[w]	Wheat straw	Loose mulch	Permanent
Straw blanket (S1000) with polypropylene netting (Enviroscape ECM, Oakwood, OH)	Wheat straw and polypropylene netting	ECB	Permanent
Thermal blanket (crop protection fabric, 3.0 oz/yard²; Dewitt Co.)	Needle-punch, nonwoven polypropylene	NA	Temporary

[z]1 mil = 0.0254 mm, 1 oz/yard² = 33.9057 $g \cdot m^{-2}$, 1 lb/1000 ft² = 48.8243 $kg \cdot ha^{-1}$.
[y]Information about the material used to construct the covers were available from company websites or other sources.
[x]Classification of erosion control materials from the Erosion Control Technology Council (Lancaster and Austin, 2003). Germination covers are not typically classified as an erosion control material due to their temporary use, but some limited erosion reduction would be expected from these products due to their ability to limit soil particles from being dislodged; NA = not applicable, ECB = erosion-control blankets.
[w]The straw bale size used was 14 inches high × 18 inches wide × 40 inches (35.6 × 45.7 × 101.6 cm) long, weighing 49 lb (22.2 kg) per bale.

DAP, when a majority of the species had reached full coverage. Soil temperature was continuously (every 30 min) monitored for 1 month after planting with probes (Hobo TMC50-HD and Hobo H8 logger; Onset Computer, Bourne, MA) at a depth of 0.75 inch in two of the three replications and logged. Volumetric soil moisture at a 3.0 inch depth was measured in five subplots in each plot immediately before cover removal 14 DAP using a time domain reflectometry moisture meter (TDR300; Spectrum Technologies, Plainfield, IL). The amount of photosynthetically active radiation (*PAR*) penetration allowed was measured for each cover technology each year. Each cover was positioned over an 18 × 18-inch glass plate on a clear, cloudless day at solar noon and a quantum light meter (3415F; Spectrum Technologies) was used to measure the amount of *PAR* that passed through each cover technology at nine random positions with each position being used as a replicate during analysis. A subsample, equivalent to the application rate, was used to quantify *PAR* below straw. The amount of transmittance through glass alone was used as the *PAR* level for the control. Data from each experiment were analyzed via analysis of variance (ANOVA) using SAS (version 9.1; SAS Institute, Cary, NC). Means were separated using Fisher's protected least significant difference when F tests were significant at $\alpha = 0.05$. A performance index was used to compare differences among cover technologies. Performance index was determined for each year as the number of times each cover technology was associated with turfgrass establishment ratings ranked in the highest statistical category within turf species.

Results

Year × cover technology × species interactions were significant (ANOVA not shown), therefore data for each year were analyzed and presented separately. There was a significant ($P < 0.0001$) cover × species interaction in each year, thus, data are presented separately for each species. Similar trends in turfgrass coverage existed across data collection periods within year, therefore only data from 45 and 35 DAP in 2007 and 2008, respectively, are reported and discussed. Establishment was higher ($P = 0.0007$) in 2008 compared with 2007 with 44% coverage 45 DAP across species and cover technology in 2007 (Table 2) and 56% coverage 35 DAP across species and cover technology in 2008 (Table 3).

Straw-covered plots and the control were the only two treatments that did not allow maximum bermudagrass establishment in 2007 (Table 2). Bermudagrass coverage was highest in plots covered with Deluxe and Futerra products, jute, Poly Jute, Thermal blanket, and the control in 2008 (Table 3). Bermudagrass coverage was lowest in straw-covered plots in 2008, although the Curlex, polyethylene, and straw blanket plots also has less bermudagrass establishment than Deluxe (Table 3). Results were consistent across years except for the control and polyethylene-covered plots. The control plots had the lowest coverage of all treatments in 2007, but performed in the top statistical group in 2008. Polyethylene-covered plots performed in the top group in 2007, but had the lowest coverage of all cover technology treatments in 2008.

Curlex and Futerra products, jute, Poly Jute, straw, and straw blanket allowed for the highest buffalograss establishment in 2007, whereas the control and Thermal blanket plots had the lowest establishment (Table 2). Buffalograss coverage was highest in plots covered with Curlex, Deluxe, and Futerra products, jute, Poly Jute, straw blanket, Thermal blanket, and the control in 2008 (Table 3). Buffalograss coverage was lowest in the polyethylene-covered plots and straw-covered plots and both had less establishment than Deluxe (Table 3). Results were consistent across years except for the control and the Thermal blanket, which had less coverage than most cover technology treatments in 2007, but performed in the top statistical group in 2008.

Curlex and Futerra products, jute, Poly Jute, straw, and straw blanket allowed for the greatest centipedegrass establishment in 2007 (Table 2). No centipedegrass established in the control in 2007. Centipedegrass coverage was highest in plots covered with Curlex, Deluxe, and Futerra products, jute, Poly Jute,

Table 2. Turfgrass coverage in 2007, 45 d after seeding five warm-season grass species under various cover technology treatments.

	Turf coverage (%)					
Cover treatment[z]	Bermudagrass	Buffalograss	Centipedegrass	Seashore paspalum	Zoysiagrass	Mean
Curlex	94 a[y]	53 a	23 a	50 b	23 ab	49
Deluxe	100 a	28 c	5 bcd	80 a	9 abc	44
Futerra	100 a	41 abc	20 abc	90 a	25 a	55
Futerra F4 Netless	99 a	50 a	24 a	80 a	25 a	59
Jute	96 a	42 abc	15 a-d	87 a	13 abc	51
Poly Jute	99 a	50 a	8 a-d	84 a	12 abc	57
Polyethylene	99 a	30 bc	2 d	85 a	10 abc	45
Straw	76 b	50 a	8 a-d	47 bc	8 abc	39
Straw blanket	83 ab	40 abc	10 a-d	32 c	8 abc	35
Thermal blanket	100 a	9 d	4 c-d	60 b	7 bc	36
Control	73 b	6 d	0 d	8 d	3 c	18
Mean	92	37	11	63	13	44

[z]See Table 1 for a full description of the cover technology and its construction.
[y]Mean of three replicates. Within columns, means followed by the same letter are not significantly different according to Fishers's protected least significant difference at $\alpha = 0.05$.

Table 3. Turfgrass coverage in 2008, 35 d after seeding five warm-season grass species under various cover technology treatments.

	Turf coverage (%)					
Cover treatment[z]	Bermudagrass	Buffalograss	Centipedegrass	Seashore paspalum	Zoysiagrass	Mean
Curlex	69 b[y]	73 abc	58 ab	32 cd	40 ab	54
Deluxe	93 a	88 a	63 a	67 a	50 a	72
Futerra	75 ab	73 abc	60 ab	52 abc	42 a	60
Futerra F4 Netless	72 ab	68 abc	53 ab	42 bcd	42 a	55
Jute	83 ab	83 ab	58 ab	53 abc	47 a	65
Poly Jute	85 ab	73 abc	42 ab	53 abc	33 ab	57
Polyethylene	68 b	53 c	18 c	28 d	47 a	43
Straw	35 c	62 bc	38 bc	20 d	18 b	35
Straw blanket	65 b	78 ab	45 ab	28 d	32 ab	50
Thermal blanket	73 ab	72 abc	52 ab	40 bcd	48 a	57
Control	87 ab	78 ab	53 ab	60 ab	42 a	64
Mean	73	73	49	43	40	56

[z]See Table 1 for a full description of the cover technology and its construction.
[y]Mean of three replicates. Within columns, means followed by the same letter are not significantly different according to Fishers's protected least significant difference at $\alpha = 0.05$.

straw blanket, Thermal blanket, and the control in 2008 (Table 3). Centipedegrass coverage was lowest in the polyethylene- and straw-covered plots. Results were similar between years except for the control, Deluxe, and Thermal blanket, which had less coverage than most cover technology treatments in 2007.

Thermal blanket and Curlex allowed less seashore paspalum establishment than Deluxe, and Futerra products, jute, Poly Jute, and polyethylene in 2007, but more than straw blanket in 2007. Among cover technologies, seashore paspalum establishment was lowest for straw and straw blanket, but both produced more coverage than the control (Table 2). Seashore paspalum coverage was highest in plots covered with Deluxe, Futerra, jute, Poly Jute, and the control in 2008 (Table 3). Seashore paspalum coverage was lowest in plots covered with Curlex, Futerra F4 Netless, polyethylene, straw, straw blanket, and Thermal blanket in 2008. Results were similar between years except for the control and polyethylene treatments. The control plots had lower coverage than all cover technology treatments in 2007, but performed in the top statistical group in 2008. Polyethylene-covered plots performed in the top statistical group in 2007, but performed in the bottom statistical group in 2008.

Zoysiagrass coverage under Futerra products and Curlex was greater than the control in 2007 (Table 2). Excluding Futerra products and the control, all other cover technologies allowed for similar zoysiagrass establishment in 2007. Zoysiagrass establishment was similar for all products in 2008 except the straw treatment, which had the lowest coverage (Table 3). All products except for straw, Thermal blanket, and the control allowed maximum zoysiagrass establishment in both years.

There were key species × cover technology interactions ($P < 0.0001$). Notably, seashore paspalum coverage was reduced when planted under Curlex blanket compared with Deluxe, but buffalograss, centipedegrass, and zoysiagrass establishment were not reduced (Tables 2 and 3). Polyethylene reduced establishment of buffalograss and centipedegrass in both years as well as bermudagrass and seashore paspalum in 2008, but zoysiagrass establishment was not reduced in either year. Straw blanket reduced establishment of seashore paspalum in both years, but coverage of buffalograss, centipedegrass, and zoysiagrass was not reduced in either year, and bermudagrass establishment was reduced only in 2008. Finally, Thermal blanket allowed for optimum bermudagrass establishment in both years, but reduced the establishment of other species in one or both years.

Maximum and mean soil temperature at a 0.75-inch depth varied for each cover technology in 2007 and 2008, although there was no difference in the minimum soil temperature among treatments in either year (Table 4). The maximum soil temperature was highest (43.7 °C) under polyethylene-covered plots followed by Deluxe (34.6 °C) in 2007. Maximum soil temperatures were lowest (≤33.4 °C) under straw, straw blanket, Thermal blanket, Futerra products, and jute in 2007. The maximum soil temperatures were highest (46 °C) under polyethylene-covered plots in 2008, and all other treatments had similar maximum soil temperatures. The mean soil temperatures were greatest for polyethylene-covered plots in both years. Mean soil temperatures were similar for Curlex, Deluxe, Poly Jute, and the control although all were lower than polyethylene in 2007. Mean soil temperatures were lowest (≤24.2 °C) under straw, straw blanket, Thermal blanket, and Futerra products. Mean soil temperatures were similar under all cover technologies except polyethylene in 2008.

Photosynthetically active radiation penetration values are reported as the percentage of *PAR* passing through the cover technologies and reaching the soil surface. Deluxe and polyethylene were among the cover technologies that allowed for the greatest (>80%) percentage of *PAR* to penetrate to the soil surface in both years (Table 5). Straw blanket, straw, jute, and Futerra F4 Netless allowed the lowest (<36%) *PAR* penetration in 2007. Straw allowed for the lowest (7%) *PAR* penetration in 2008.

There was no relationship (r = 0.31, P = 0.36 in 2007; r = 0.14, P = 0.19 in 2008) between the soil

Table 4. Soil temperature under various cover technologies tested in 2007 and 2008 for their effect on the establishment of five warm-season grasses (bermudagrass, buffalograss, centipedegrass, seashore paspalum, and zoysiagrass) from seed.

	Soil temp (°C)[z]					
	2007			2008		
Cover treatment[y]	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Curlex	17.7[x]	32.6 cd[w]	24.6 bc	17.1	34.2 c	25.9 b
Deluxe	17.7	34.6 b	24.9 b	17.8	38.0 bc	27.1 b
Futerra	18.1	32.6 cd	24.2 cde	17.1	33.6 c	25.6 b
Futerra F4 Netless	17.7	32.6 bcd	24.2 cde	17.3	33.6 c	25.7 b
Jute	17.5	33.4 bc	24.3 cd	17.4	33.7 c	25.4 b
Poly Jute	17.5	34.1 bc	24.5 be	17.0	35.4 bc	25.5 b
Polyethylene	17.5	43.7 a	27.9 a	17.0	46.0 a	30.0 a
Straw	18.1	31.9 d	24.1 cde	17.1	35.1 bc	25.2 b
Straw blanket	17.7	31.9 d	23.7 e	17.3	33.8 c	25.1 b
Thermal blanket	17.5	32.8 cd	23.8 de	17.0	34.1 bc	25.0 b
Control	17.5	34.7 b	24.4 bc	16.8	33.4 c	25.2 b
Mean	17.7	34.4	24.7	17.2	35.7	26.1
Significance[v]	NS	***	***	NS	**	*

[z]$(1.8 \times °C) + 32 = °F$.
[y]See Table 1 for a full description of the cover technology and its construction.
[x]Mean of two replicates.
[w]Within columns, means followed by the same letter are not significantly different according to Fishers's protected least significant difference at $\alpha = 0.05$.
[v]NS, *, **, ***Not significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 5. Percentage of photosynthetically active radiation (*PAR*) penetration through each cover technology and soil moisture under each cover technologies in 2007 and 2008.

	PAR penetration (%)[y]		Soil moisture (%)[x]	
Cover treatment[z]	2007	2008	2007	2008
Curlex	46 d[w]	46 e	25.5 cd	27.0 bc
Deluxe	85 b	85 bc	37.0 bcd	28.2 bc
Futerra	38 de	29 f	37.8 bc	27.2 bc
Futerra F4 Netless	31 ef	40 e	36.8 bcd	27.1 bc
Jute	35 ef	38 ef	35.1 d	26.9 bc
Poly Jute	86 b	78 c	36.2 cd	26.1 c
Polyethylene	81 b	89 b	41.5 a	30.5 a
Straw	26 f	7 g	35.6 cd	27.3 bc
Straw blanket	34 ef	37 ef	39.0 b	27.4 bc
Thermal blanket	68 c	61 d	32.6 e	27.6 bc
Control	100 a	100 a	41.6 a	28.9 ab
Mean	57	51	36.2	27.7
Significance[v]	***	***	***	*

[z]See Table 1 for a full description of the cover technology and its construction.
[y]Percentage of *PAR* of the control (full-sun) treatment. Mean of nine replicates.
[x]Mean percentage of volumetric soil moisture at a 3.0-inch (7.6 cm) depth measured 14 d after seeding in five subplots in each of three replications across five turfgrass species (n = 75).
[w]Within columns, means followed by the same letter are not significantly different according to Fishers's protected least significant difference at $\alpha = 0.05$.
[v]*, **, ***Significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

moisture underneath the cover technologies (Table 5) and mean establishment across turfgrass species (Tables 2 and 3). Soil under polyethylene-covered plots had the highest soil moisture, but this was not different from the control plots in both years. The soil moisture under other cover technologies was less than or similar to the soil moisture in the control.

Discussion

Establishment was higher in 2008 compared with 2007 ($P = 0.0007$), which could have been due to differences in temperature between the years. In 2008, the mean air temperature was 1.9 °C higher than in 2007 during the experiment and the mean soil temperatures during the first two weeks following planting was 1.4 °C higher in 2008 than in 2007 (Table 4). Bermudagrass established the quickest of all species tested in this study, while zoysiagrass and centipedegrass were generally the slowest to establish. This was not unexpected because it is known that zoysiagrass requires 90 to 105 d to reach 90% coverage, whereas bermudagrass requires only 30 to 60 d to reach 90% coverage (Patton et al., 2004).

Bermudagrass and seashore paspalum establishment was reduced in straw-covered plots in 2007 and all species had reduced establishment in straw-covered plots in 2008 (Tables 2 and 3). Although soil temperature (Table 4) and moisture (Table 5) were similar to other cover technologies in straw-covered plots, straw allowed the lowest *PAR* penetration of all the cover technologies. Light is known to be an important factor in the germination and establishment of warm-season grasses (Jellicorse et al., 2009; Shin et al., 2006; Yeam et al., 1981; Zuk et al., 2005), and it is likely that these plots did not establish well due to limited *PAR*, which inhibited germination. Specifically, bermudagrass germination was reduced when receiving ≤40% irradiance (Jellicorse et al., 2009). Several cover technologies tested in this study, including straw, were below this 40% threshold. These results are consistent with a previous report by Portz et al. (1993) in which they reported that straw was not a successful cover treatment for establishing zoysiagrass. The bale size used in this study was 14 inches high by 18 inches wide by 40 inches long, weighing 49 lb per bale. The rate (80 lb/1000 ft^2) tested in this trial was the same as Portz et al. (1993) and is consistent with recommendations from turfgrass textbooks, which is 1.5 bales of straw per 1000 ft^2. However, a reduced rate of straw (1.0 bales/1000 ft^2, 50 lb/1000 ft^2) may provide better results with warm-season grasses by increasing *PAR* penetration.

There were few differences in soil moisture between treatments in this study, with the exception of polyethylene-covered plots, which had the highest soil moisture. Frequent rainfall events in both years, 1 to 2 days before sampling, kept the soil moist and this was likely why there were few differences in soil moisture between treatments.

Polyethylene reduced establishment of buffalograss and centipedegrass in both years and reduced bermudagrass and seashore paspalum in 2008 (Tables 2 and 3). Zoysiagrass establishment was not reduced by polyethylene covers. Temperatures under polyethylene covers increased to 43.7 °C in 2007 and 46 °C in 2008. Observations suggest that seedling germination was not inhibited under polyethylene covers, as seedlings were first to germinate under this cover in both years, but the high temperatures under this cover technology likely reduced establishment by injuring seedlings following germination. The germination of warm-season turfgrasses increases as temperatures rise, with maximum germination rate occurring between 25 and 40 °C (Bush et al., 2000; Portz et al., 1981; Sandlin et al., 2006; Shin et al., 2006; Zuk et al., 2005) depending on species. Maki et al. (1989) reported that zoysiagrass seedlings can be injured or killed at temperatures above 50 °C, although Portz et al. (1993) found little inhibition on germination and growth at 60 °C. Both of these reports are consistent with this study because zoysiagrass establishment was not reduced at a maximum of 46 °C. Bermudagrass germination ceases when temperatures reach 50/40 °C day/night (Sandlin et al., 2006), which is lower than zoysiagrass and may explain why bermudagrass establishment was lower in 2008. Additionally, Sowers and Welterlen (1988) documented that bermudagrass establishment from sprigs was reduced in the summer when covered with plastic due to supraoptimal temperatures exceeding 41 °C. There are no reports on the germination and establishment of buffalograss, centipedegrass, and seashore paspalum at temperatures exceeding 40 °C, although results of this study suggest that their establishment may be inhibited at high temperatures.

Raymer et al. (2005) reported that seashore paspalum was successfully established by seed using plastic covers similar to the polyethylene cover used in this study. However, the plastic covers tested by Raymer et al. (2005) were perforated, which prevented excessive temperature buildup while still allowing for increased soil warming. Because the optimum germination temperature for seashore paspalum is 35 °C (Shin et al., 2006), perforated polyethylene covers would likely provide for improved establishment over the unperforated polyethylene covers used in our study. Portz et al. (1993) reported the successful use of perforated polyethylene covers to establish zoysiagrass from seed (Portz et al., 1993). However, the commercial availability of perforated polyethylene covers is limited.

Thermal blanket inhibited establishment of seashore paspalum in both years, as well as buffalograss, centipedegrass, and zoysiagrass in 2007 (Tables 2 and 3). Thermal blanket has a similar construction to Deluxe (Table 1), although Deluxe allowed more seashore paspalum to establish in both years. Thermal blanket has a heavier construction, which may have negatively influenced seedling germination through additional shading of seedlings compared with Deluxe (Table 5).

Control plots performed well in 2008 and poorly in 2007, suggesting that seed covers are not always needed for successful establishment. Soil temperature was warmer in 2008 than 2007, which may have helped improve establishment (Table 5). Additionally, precipitation events in 2007 were more frequent, and rain splash may have compacted the surface layer of soil, causing reduced establishment in the control. Although not all cover technologies improved establishment compared with the control, most cover technologies are beneficial for reducing erosion during establishment (Krenitsky et al., 1998).

Deluxe and Futerra products, jute, and Poly Jute allowed for improved establishment in most cases (Table 6). Curlex, straw blanket, and Thermal blanket produced intermediate results and allowed improved establishment with certain species. With the exception of straw and polyethylene, cover technologies used in this study allowed for >28% *PAR* penetration with adequate soil moisture (Table 5) and prevented the build-up of excessive temperatures (Table 4). There were some key species × cover technology interactions such as the reduction of seashore paspalum coverage when using Curlex, but there was no obvious reason as to why this occurred.

Overall, Deluxe and Futerra products, jute, and Poly Jute allowed for the highest establishment of these seeded warm-season grasses (Table 6). Costs for these cover technologies range from $20 to $76/1000 ft^2 (Table 6). Other technologies such as Curlex, straw blanket, and Thermal blanket produced intermediate results and allowed for improved establishment with certain species. Polyethylene covers should not be used except with zoysiagrass or except when perforated. Straw should not be used for the establishment of warm-season grasses at the rate tested in this trial. Control plots performed well in 2008 and poorly in 2007, suggesting

Table 6. Performance index of cover technologies in establishing five warm-season turfgrasses (bermudagrass, buffalograss, centipedegrass, seashore paspalum, and zoysiagrass) from seed.

Cover treatment[z]	Performance index[y] 2007	2008	Total	Approximate cost ($/1000 ft^2)[x]
Curlex	4	3	7	64
Deluxe	3	5	8	20
Futerra	5	5	10	59
Futerra F4 Netless	5	4	9	63
Jute	5	5	10	76
Poly Jute	5	5	10	62
Polyethylene	3	1	4	30
Straw	3	0	3	6
Straw blanket	4	3	7	39
Thermal blanket	1	4	5	61
Control	0	5	5	—

[z]See Table 1 for a full description of the cover technology and its construction.
[y]Performance index was determined for each year as the number of times each cover technology was associated with turfgrass establishment ratings ranked in the highest statistical category within turf species. For each year, the potential maximum value is 5, with a cumulative potential maximum total of 10.
[x]Cost estimates based on three sources. Estimate does not including shipping or installation labor; $1/1000 ft^2 = $107.6391/ha.

that seed covers are not always needed for successful establishment. Typically, most seed cover technologies will be useful for the establishment of warm-season grasses from seed, especially for reducing erosion during establishment. The use of cover technologies with erosion control properties (Table 1) is especially important when establishing slow-growing species such as centipedegrass and zoysiagrass on sloped sites. Although only establishment was examined in this study, future work should also examine the effect of cover technologies on warm-season grass germination rate and percentage.

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