Stolon Growth Characteristics and Establishment Rates of Zoysiagrass Progeny

David O. Okeyo, Jack D. Fry¹, and Dale J. Bremer

Department of Horticulture, Forestry, and Recreational Resources, Kansas State University, 2021 Throckmorton Plant Science Center, Manhattan, KS 66506

Ambika Chandra, Dennis Genovesi, and Milton C. Engelke

Texas A&M AgriLife Urban Solutions Center, 17360 Coit Road, Dallas, TX 75252

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Abstract. Zoysiagrass (*Zoysia* spp.) is recognized for its low requirements for pesticide and fertilizer input, but Meyer (*Z. japonica* Steud.), the cultivar commonly used in the transition zone of the United States, is slow to establish. We evaluated new zoysiagrass progeny for stolon growth characteristics and rate of establishment and determined the relationship between stolon growth characteristics and coverage. ‘Meyer’, DALZ 0102 (a *Z. japonica*), and 18 progeny from crosses of ‘Emerald’ (*Z. japonica* × *Z. tenuifolia* Willd. ex Thiele) or a *Z. matrella* (L.) Merr. × *Z. japonica* were planted as 6-cm diameter plugs on 30.5 × 30.5-cm centers in 1.5 × 1.5-m plots in 2007 and as single 10-cm diameter plugs in 1.2 × 1.2-m plots in 2008 in Manhattan, KS. Data were collected weekly on number of stolons initiated per plug, stolon elongation, and number of stolon branches. Two researchers rated coverage visually near the end of each growing season. Rate of stolon initiation ranged from 2.2/week to 8.6/week. Elongation rate ranged from 18.8 to 65.1 mm/week. At 11 weeks after planting in 2007, four of 18 progeny had superior coverage to ‘Meyer’; at 11 weeks after planting in 2008, 13 of 18 progeny had superior coverage to ‘Meyer’. Rate of stolon initiation was positively correlated ($P < 0.01$) with zoysiagrass coverage ($r = 0.66$, in 2007; $r = 0.94$ in 2008); likewise, stolon elongation was positively correlated with coverage in 2007 ($r = 0.52$, $P < 0.01$) and 2008 ($r = 0.53$, $P < 0.05$). Stolon initiation or elongation could be used in short-term evaluations to predict rate of zoysiagrass coverage from plugs. Greater stolon initiation or elongation of experimental some zoysiagrass progeny makes them promising for alternatives to ‘Meyer’ for overcoming slow establishment rates.

Japanese lawngrass (*Z. japonica*) and Manilagrass (*Z. matrella*) are collectively referred to as zoysiagrass in the United States; however, *Z. japonica* is more cold-hardy than the *Z. matrella* (Patton, 2009). Meyer zoysiagrass, a *Z. japonica* cultivar, has been the predominant cultivar used in the transition zone since its release in 1952 as a result of its good freezing tolerance and low pesticide and nitrogen requirements (Fry and Huang, 2004). Since the release of ‘Meyer’, researchers at Texas A&M University have developed several *Z. matrella* cultivars with high turf quality, including better density, finer texture, and better color compared with ‘Meyer’. Among

these cultivars are Diamond, Cavalier, and Zorro. Unfortunately, these cultivars are not suitable for use in the transition zone as a result of lack of freezing tolerance (Fry and Huang, 2004).

Since 2004, turfgrass researchers at Kansas State University have evaluated over 600 new zoysiagrass progeny for winter survival and quality (Fry et al., 2008). These progeny were the result of interspecific crosses made at Texas AgriLife Research-Dallas Urban Solutions Center, most of which involved one parent from *Z. japonica* and one from a *Z. matrella* cultivar or ‘Emerald’ zoysiagrass. The ideal result of these efforts would be a dense, fine-textured zoysiagrass with quality similar to the aforementioned *Z. matrella* cultivars but freezing tolerance as good as or better than ‘Meyer’.

One of the primary complaints regarding ‘Meyer’ from transition zone turf managers is its slow rate of vegetative establishment (Patton and Reicher, 2007; Patton et al., 2004, 2006; Zuk and Fry, 2005). Although cultural practices have been evaluated for their effects on rate of zoysiagrass establishment, most of them have been shown to have little effect (Fry and Dernoeden, 1987; Patton

and Reicher, 2007; Richardson and Bordelon, 2000; Richardson and Boyd, 2001).

Researchers have shown that zoysiagrasses vary widely in establishment rate, which is dependent on genotype. Cultivars of *Z. japonica* have been reported to have the fastest establishment rate followed by *Z. matrella* and then *Z. tenuifolia* (Brosnan and Deputy, 2008; Patton and Reicher, 2007).

Fry (1984) compared the establishment rate and stolon growth characteristics of five *Z. japonica* lines, ‘Emerald’, and a *Z. matrella* cultivar in Maryland. When planted as 5-cm diameter plugs on 30-cm centers, ‘Midwest’, a *Z. japonica*, and Bel-Zrt-1, an experimental *Z. japonica*, had the greatest coverage rate. Coverage of ‘Meyer’ was comparable to ‘Belair’ (*Z. japonica*), ‘Emerald’, and *Z. matrella*. The *Z. matrella* produced the greatest number of stolons, but all others were similar. Bel-Zrt-1 and ‘Midwest’ had the longest stolons, but ‘Meyer’ had the most nodes per stolon.

Z. japonica cultivars that had been seeded or planted vegetatively had greater coverage 91 d after planting than vegetatively established *Z. matrella* cultivars in Indiana (Patton et al., 2007). In particular, the *Z. japonica* lines DALZ 0102, ‘El Toro’, and ‘Chinese Common’ were among those exhibiting the fastest rate of coverage. Conversely, ‘Emerald’ and the *Z. matrella* cultivars Cavalier and Diamond were among the slowest cultivars both in terms of rate of coverage and stolon elongation rates. ‘Zorro’, another *Z. matrella*, had a faster establishment rate than ‘Cavalier’, ‘Diamond’, or ‘Meyer’ (Patton et al., 2007).

In southern California, a comparison of establishment rates of ‘El Toro’ (*Z. japonica*), ‘Emerald’, and a selection from *Z. matrella* indicated that ‘El Toro’ was fully established in 3 months, whereas ‘Emerald’ and the *Z. matrella* required 4 months for complete coverage, whether established from plugs or sprigs (Gibeault and Cockerham, 1988).

More information is needed on growth characteristics and establishment rates of promising zoysiagrasses that could be used in the transition zone. Therefore, our objective was to evaluate the stolon growth characteristics and establishment rates of new zoysiagrass progeny and determine the relationship among these characteristics and coverage.

Materials and Methods

Two separate studies were conducted at the Rocky Ford Turfgrass Research Center, Manhattan, KS (long. 39.128° N, lat. 96.358° W) in 2007 (Study I) and 2008 (Study II). Soil was a Chase silt loam (fine, montmorillonitic, mesic, Aquic, Argiudolls). The same 20 grasses were evaluated in each study and consisted of ‘Meyer’ and DALZ 0102, an experimental *Z. japonica* that was included in the 2002 National Turfgrass Evaluation Program Zoysiagrass Evaluation (Morris, 2006) and 18 zoysiagrass progeny. All of the progeny originated from crosses of ‘Emerald’ or

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¹To whom reprint requests should be addressed; e-mail jfry@ksu.edu.

a *Z. matrella* × *Z. japonica*. The parental lines and progeny resulting from those crosses evaluated are shown in Table 1. DALZ 8501 is an experimental *Z. matrella* that was never commercially released. The four-digit prefix code assigned by Texas AgriLife Research to the progeny is the same within a particular cross. For example, all grasses assigned the 5311 prefix originated from crosses of ‘Cavalier’ × ‘Chinese Common’. The extension number represents different progeny within the family. In preliminary field evaluations, these 18 progeny have exhibited good turf quality characteristics and no winter injury in the field since 2004 (Okeyo, 2010).

Before experiments, soil pH was 7.3, phosphorus level was 123 mg·kg⁻¹, and potassium level was 475 mg·kg⁻¹. Just after planting in each study, oxadiazon [5-tert-butyl-3-(2, 4-dichloro-5-isopropoxyphenyl)-1, 3, 4-oxadiazol-2(3H)-one] was applied to prevent emergence of annual grasses at a rate of 3.4 kg·ha⁻¹. Irrigation was applied 3 d weekly during each study period to provide ≈25 mm water per week. Turf was not mowed either year. A weather station located within 100 m of the study area was used to monitor air temperature. In addition, a soil-encapsulated thermocouple assembled according to Ham and Senock (1992) was installed 2.5 cm deep in one plot of each replicate to monitor soil temperature. Soil temperature was recorded hourly using a data logger (CR-10x; Campbell Scientific, Inc., Logan, UT). Five-d

averages of minimum and maximum air and soil temperatures at the study site in 2007 and 2008 are shown in Figure 1.

Study I, 2007. Plugs of zoysiagrass measuring 6 cm in diameter were propagated in the greenhouse during the winter and spring of 2007. On 5 June 2007, 16 plugs of each zoysiagrass were planted on 30.5 cm × 30.5-cm centers in 1.5 m × 1.5-m plots at the Rocky Ford Turfgrass Research Center, Manhattan, KS. Total precipitation by month during the study period was as follows: 5 to 30 June, 57 mm; 1 to 31 July, 103 mm; 1 to 31 Aug., 51 mm; and 1 to 24 Sept., 44 mm. The plots were arranged in a randomized complete block with three replications per progeny or cultivar. Urea (46N–0P–0K) was applied to provide nitrogen at 49 kg·ha⁻¹ on 12 July and 31 Aug. 2007.

Data were collected on stolon initiation, elongation, branching, and percent plot coverage. The number of stolons, stolon length, and number of branches were determined weekly from 18 June to 1 Aug. using three randomly selected plugs from each plot. Stolon initiation was determined by counting the number of stolons originating from each plug. Stolon elongation and branching were evaluated on each of the first three stolons emerging from three randomly selected plugs. Each of the stolons used to evaluate elongation and branching was labeled with a loose knot of thread tied around the stolon to facilitate its identity. Elongation was deter-

mined by inserting a colored plastic toothpick in the ground at the tip of the stolon. The next week, after elongation had occurred, the distance was measured from the end of the stolon back to the location of the toothpick. Branching was determined by counting the number of new branches that were at least 2 cm long on the same stolons used for elongation measurements. Percentage coverage was rated visually by two researchers on 24 Aug. and 24 Sept. 2007 using a 0% to 100% scale.

Study II, 2008. On 23 June 2008, grasses were obtained as single 10-cm diameter plugs from plots at the Olathe Horticulture Research Center, Olathe, KS. Each of the individual 10-cm diameter plugs was then planted in the center of a 1.2 m × 1.2-m plot at the Rocky Ford Turfgrass Research Center in Manhattan, KS, on 24 June. Single plugs were used because, unlike 2007, we had no intention of establishing larger plots to be used in additional experiments. Total precipitation by month during the study period was as follows: 24 to 30 June, 32.5 mm; 1 to 31 July, 127 mm; 1 to 31 Aug., 115 mm; and 1 to 4 Sept., 2 mm. Plots were arranged in a randomized complete block design with three replicates. Urea was applied to provide nitrogen at 49 kg·ha⁻¹ on 14 July and 12 Aug. 2008.

Stolon initiation, elongation, and branching were determined weekly starting on 1 July and ending on 4 Sept. 2008. Stolon initiation was determined by counting all

Table 1. Average weekly rates of stolon initiation, elongation, and branching of zoysiagrasses at Manhattan, KS, in 2007 and 2008.^z

Cultivar or progeny	Stolon initiation (no./week) ^y		Stolon elongation (mm/week) ^x		Stolon branching (no./week) ^w	
	Study I 2007	Study II 2008	Study I 2007	Study II 2008	Study I 2007	Study II 2008
Meyer	2.9 c ^v	3.4 b	38.0 bc	26.8 cd	5.6 ab	5.6 ab
DALZ 0102	2.6 c	7.5 ab	26.4 c	36.3 bc	4.1 b	5.4 ab
Cavalier × Meyer (5283-27)	4.7 b	6.9 ab	35.1 bc	41.9 bc	4.7 ab	6.8 ab
Cavalier × Chinese Common						
5311-3	5.6 ab	7.2 ab	53.3 ab	36.7 bc	4.6 ab	1.8 c
5311-8	4.6 b	6.5 ab	46.2 b	35.0 bc	3.7 b	4.4 bc
5311-22	6.3 a	7.6 ab	55.7 ab	46.0 bc	4.7 ab	3.7 bc
5311-26	5.0 ab	5.3 b	34.1 bc	39.6 bc	3.5 b	3.0 c
5311-27	4.8 ab	7.9 ab	43.6 b	46.3 bc	3.2 b	4.5 bc
5311-32	4.7 b	7.7 ab	49.3 ab	46.0 bc	4.2 b	5.1 bc
Zorro × Chinese Common						
5312-36	4.1 bc	7.8 ab	58.0 ab	49.1 b	5.2 ab	6.4 ab
5312-49	3.5 bc	5.3 b	61.9 a	65.1 a	3.6 b	6.5 ab
Emerald × Meyer						
5321-3	4.9 ab	8.6 a	39.6 bc	40.3 bc	3.6 b	4.6 bc
5321-24	2.9 c	7.6 ab	21.6 c	30.6 cd	3.4 b	5.1 bc
5321-45	2.4 c	4.6 b	37.4 bc	33.5 c	4.7 ab	5.4 b
5321-48	2.2 c	3.2 b	21.3 c	18.8 d	2.6 b	4.4 bc
DALZ 8501 × Meyer						
5324-18	5.3 ab	8.4 a	54.8 ab	43.2 bc	6.0 ab	7.7 a
5324-27	4.7 ab	7.8 ab	32.0 bc	37.8 bc	2.3 b	6.7 ab
5324-52	2.6 c	5.5 b	32.5 bc	29.1 cd	3.8 b	6.2 ab
5324-53	4.1 bc	7.1 ab	58.1 ab	39.1 bc	7.1 a	5.3 b
Meyer × Diamond (5327-19)	3.2 bc	4.9 b	46.5 b	29.8 cd	5.1 ab	3.6 bc

^zGrasses were planted as 6-cm diameter plugs on 30.5-cm centers in 1.5 m × 1.5-m plots on 5 June 2007. In 2008, individual 10-cm diameter plugs were planted on 24 June in plots measuring 1.2 m × 1.2 m. Weekly Rates of stolon initiation, elongation, and branching of zoysiagrasses were calculated from 18 June to 24 Sept. in 2007 and from 1 July to 4 Sept. in 2008 using PROC REG (SAS Institute, Inc., 2003) to obtain slope estimates.

^yStolon initiation per week is the average of three replicates from three randomly selected plugs per plot in 2007 and an average of a single plug over three replicates in 2008.

^xStolon elongation per week is the average length of one stolon from three randomly selected plugs per plot, and over three replicates, in 2007. Stolon elongation per week in 2008 is the average of three randomly selected stolons per plug and three replicates.

^wStolon branching per week is the average number of branches on one stolon from three randomly selected plugs per plot and over replicates in 2007. In 2008, branching per week is the average of three selected stolons per plug over three replicates.

^vMeans followed by the same letter in a column are not significantly different according to Bonferroni's *t* test at *P* ≤ 0.05 (corrected for multiple comparisons).

stolons from the single plug planted in each plot. Elongation and branching were determined as described previously for the first three stolons that emerged from each plug. Percent plot coverage was rated visually by two researchers on 4 Sept.

Data analyses. Stolon initiation data were averaged over the three plugs per plot in 2007 as were stolon length and number of branches for nine stolons per plot in 2007 and three stolons per plot in 2008. Data on percent coverage taken by two researchers were also averaged to obtain a single value for each of plot. Both stolon growth and coverage data were transformed by taking the square root before analysis. Stolon growth data were subjected to linear regression analysis to determine slopes of lines (rates) using PROC REG (SAS Institute, Inc., 2003). Progeny and cultivars were compared using Bonferroni's *t* test (Hochberg and Tamhane, 1987) at $P \leq 0.05$ (adjusted for multiple comparison). Coverage data were subjected to analysis of variance using SAS, and means were separated using the Ryan-Einot-Gabriel-Welsch (REGWQ) mean separation test (Hochberg and Tamhane, 1987; Mickey et al., 2004) at $P \leq 0.05$ (SAS Institute, Inc., 2003). Finally, correlation analysis was used to determine the relationships among rates of stolon initiation, elongation, and branching in each year and percentage coverage (24 Aug. and 24 Sept. 2007, and 24 Sept. 2008) using Pearson's correlation (SAS Institute, Inc., 2003).

Results and Discussion

Stolon growth characteristics. Rates of stolon initiation in Study I in 2007 ranged from 2.2/week (progeny 5321-48) to 6.3/week (5311-22) (Table 1). All grasses in the 'Cavalier' × 'Chinese Common' family cross had higher stolon initiation rates than 'Meyer' (2.9/week) as did 'Cavalier' × 'Meyer' (5283-27), one progeny from 'Emerald' × 'Meyer' (5321-3), and two progeny from 8501 × 'Meyer' (5324-18 and 5324-27).

In Study II in 2008, the highest stolon initiation rate occurred with 5321-3 (8.6/week) and the lowest rate with 5321-48 (3.2/week) (Table 1). Only 5321-3 and 5324-18 had higher stolon initiation rates than 'Meyer' (3.4/week).

Stolon elongation in Study I in 2007 ranged from 21.3 mm/week (5321-48) to 61.9 mm/week (5312-49) (Table 1). Only 5312-49 had a faster rate of stolon elongation than 'Meyer' (38 mm/week). In Study II in 2008, stolon elongation rate ranged from 18.8 mm/week (5321-48) to 65.1 mm/week (5312-49). Only the progeny from 'Zorro' × 'Chinese Common' (5312-36 and 5312-49) had a higher rate of elongation than 'Meyer' (26.8/week). Therefore, rates of elongation were consistently greater than 'Meyer' only in 5312-49 across years. In West Lafayette, IN, elongation rates observed across several *Z. japonica* and *Z. matrella* cultivars ranged from 11.9 mm/week to 79.1 mm/week (Patton

Fig. 1. Average daily minimum and maximum air and soil temperatures at the study site at Manhattan, KS, for Study I in 2007 (top) and Study II in 2008 (bottom). Data are presented as 5-d means to illustrate seasonal trends.

Table 2. Coverage of zoysiagrasses at Manhattan, KS, in 2007 and 2008.^a

Cultivar or progeny	Coverage (%) ^b		
	Study I		Study II
	24 Aug. 2007	24 Sept. 2007	4 Sept. 2008
Meyer	55.8 cd ^c	94.7 ab	50.0 d
DALZ 0102	66.7 bc	94.7 ab	90.0 ab
Cavalier × Meyer (5283-27)	53.3 cd	85.0 abcd	85.0 ab
Cavalier × Chinese Common			
5311-3	54.2 cd	90.0 abc	85.0 ab
5311-8	63.3 bc	95.0 ab	73.3 abc
5311-22	78.3 a	97.7 a	75.0 abc
5311-26	67.5 b	96.0 ab	70.0 bcd
5311-27	65.4 bc	96.3 ab	85.0 ab
5311-32	64.2 bc	94.7 ab	90.0 ab
Zorro × Chinese Common			
5312-36	60.0 c	97.7 a	85.0 ab
5312-49	66.7 bc	94.7 ab	75.0 abc
Emerald × Meyer			
5321-3	72.5 ab	99.0 a	95.0 a
5321-24	42.5 e	76.7 cd	75.0 abc
5321-45	51.7 d	85.0 abcd	56.7 cd
5321-48	43.3 e	73.3 d	50.0 d
DALZ 8501 × Meyer			
5324-18	74.2 ab	97.7 a	90.0 ab
5324-27	44.2 e	81.7 bcd	90.0 ab
5324-52	55.8 cd	86.7 abcd	70.0 bcd
5324-53	56.7 cd	93.3 ab	80.0 ab
Meyer × Diamond (5327-19)	58.3 cd	88.3 abc	70.0 bcd

^aGrasses were planted as 6-cm diameter plugs on 30.5-cm centers of 1.5 × 1.5-m plots on 5 June 2007 and as individual 10-cm diameter plugs in the center of 1.2 m × 1.2-m plots on 24 June 2008.

^bCoverage (%) is the average visual estimate of two researchers and over three replicates.

^cMeans followed by the same letter in a column are not significantly different according to Ryan-Einot-Gabriel-Welsch test at $P \leq 0.05$.

Table 3. Pearson correlation coefficients for average weekly rates of stolon initiation, elongation, branching, and coverage of zoysiagrass cultivars and progeny at Manhattan, KS, in 2007 and 2008.^z

Growth index	Stolon initiation (no./week)		Stolon elongation (mm/week)		Stolon branching (no./week)		Coverage	
	Study I 2007	Study II 2008	Study I 2007	Study II 2008	Study I 2007	Study II 2008	Study I 2007	Study II 2008
Stolon initiation (no./week)	1.000	1.000	0.573**	0.533**	0.169	0.043	0.663**	0.938**
Stolon elongation (mm/week)	0.573**	0.533**	1.000	1.000	0.554**	0.211	0.524**	0.531*
Stolon branching (no./week)	0.169	0.043	0.554**	0.211	1.000	1.000	0.317	0.188
Coverage	0.663**	0.938**	0.524**	0.531*	0.317	0.188	1.000	1.000

^zIn 2007, correlation analysis was performed on average weekly stolon initiation, elongation and branching, and coverage on 24 Aug. In 2008, correlation analysis was performed on average weekly stolon initiation, elongation, and branching and coverage on 4 Sept.

*, ** Significant at $P \leq 0.05$ or 0.01 , respectively.

et al., 2007). In the current study, we observed elongation rates that were comparable to these (19 to 65 mm/week). Earlier reports of stolon elongation rates for 'Meyer' (35 mm/week) by Patton et al. (2007) were similar to what we observed (38 mm/week in 2007 and 26.8 mm/week in 2008). Stolon elongation rates reported for DALZ 0102 (53.9 mm/week) by Patton et al. (2007) were somewhat higher than what we observed (26.4 mm/week in 2007 and 36.3 mm/week in 2008).

Stolon branching in Study I in 2007 ranged from 2.3/week (5324-27) to 7.1/week (5324-53) (Table 1). 'Meyer' was not significantly different from any progeny in rate of stolon branching. In Study II, rate of stolon branching ranged from 1.8/week (5311-3) to 7.7/week (5324-18) (Table 1). Similarly, none of the grasses was different from 'Meyer' in rate of branching.

Coverage. In Study I on 24 Aug. 2007, coverage ranged from 42.5% (5321-24) to 78.3% (5311-22) (Table 2). Progeny exhibiting higher levels of coverage than 'Meyer' (55.8%) were 5311-22, 5311-26, 5321-3, and 5324-18. By 24 Sept. 2007, coverage ranged from 73.3% (5321-48) to 99% (5321-3). However, coverage of 'Meyer' (94.7%) was not significantly different from any of the grasses except 5321-24 and 5321-48, which were lower. In Study II, coverage on 4 Sept. 2008 ranged from 50% (5321-48) to 95% (5321-3). All grasses were superior to 'Meyer' (50%) except 5311-26, 5321-45, 5321-48, 5324-52, and 5327-19.

Coverage at the end of 2008 was generally lower than at the end of 2007 (Table 2). Such differences were likely the result of a later planting date (5 June in 2007 versus 24 June in 2008) and lower initial coverage at the time of planting in 2008. In 2007, initial coverage at planting was 2% of the 2.25-m² plot; whereas in 2008, the total area covered at planting when a single plug was used per plot was 0.5% of the 1.44-m² plot. In addition, the multiple plugs planted in each plot in 2007 resulted in more overlapping stolons from plug to plug and contributed to a faster rate of coverage.

Average ground coverage of *Z. japonica* cultivars after a period of 91 d after planting in Indiana was 0.23 m², whereas coverage of cultivars of *Z. matrella* was 0.13 m² (Patton et al., 2007). In the same evaluation, 'Meyer' also had greater coverage than 'Cavalier' or 'Diamond' at 59 d after planting. In Maryland (Fry, 1984), coverage of zoysiagrass planted

using the same plot arrangements as in our evaluation in 2007 was lower (45% to 60%), which may have been the result of a sandier soil at the Maryland location. In that evaluation, 'Meyer' coverage was comparable to that of a *Z. matrella* and 'Emerald' zoysiagrass at the end of the first growing season.

Our findings indicate that some new zoysiagrass progeny have faster establishment rates than 'Meyer', which should increase their acceptance by sod producers and homeowners who choose to establish these grasses from vegetative plugs. In particular, all six crosses of 'Cavalier', traditionally a relatively slow-spreading cultivar, with 'Chinese Common', a fast-spreading type, resulted in progeny that had superior coverage compared with 'Meyer' on at least one of the three rating dates. Both progeny evaluated from 'Zorro' × 'Chinese Common' (5312-36 and 5312-49) were superior in coverage to 'Meyer' on the 4 Sept. 2008 rating date. Some progeny originating from parents not recognized for quick coverage also exhibited superior coverage to 'Meyer' on at least one rating date, including those from 'Emerald' × 'Meyer' (5321-3) and 8501 × 'Meyer' (5324-18 and 5324-27).

Correlation between stolon characteristics and coverage. In both years, the rate of stolon initiation was positively correlated with stolon elongation and coverage (Table 3). Stolon elongation was positively correlated with stolon branching in 2007 and coverage in both years. Similarly, positive correlations were observed between coverage 24 Sept. 2007 (not shown in Table 3) and stolon initiation ($r = 0.58$, $P = 0.008$), stolon elongation ($r = 0.67$, $P = 0.001$), and stolon branching ($r = 0.48$, $P = 0.032$). The positive correlation between stolon initiation or elongation rates and coverage suggests that grasses that have these characteristics will be faster to cover. Patton et al. (2007) also found that the zoysiagrass cultivars that had faster rates of stolon elongation had faster rates of establishment. In southern California, turfgrasses with greater stolon initiation had the fastest rates of plug growth and establishment among 'El Toro', 'Emerald', and a selection from *Z. matrella* (Gibeault and Cockerham, 1988).

In summary, we found that zoysiagrass cultivars and progeny from *Z. matrella* or Emerald × *Z. japonica* varied widely in the rates of stolon initiation and elongation, and both parameters were positively correlated

with percentage coverage. The positive relationship between stolon characteristics and coverage indicates that short-term evaluations of stolon initiation or elongation rate could be used to predict rate of zoysiagrass coverage from plugs. Several experimental zoysiagrass progeny evaluated had superior rates of coverage compared with 'Meyer' zoysiagrass, which make them more attractive to sod producers and homeowners. Additional research is needed to identify those that compliment fast establishment rates with superior quality characteristics and freezing tolerance.

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