Dormant Seeding Bermudagrass Cultivars in a Transition-Zone Environment

B. R. Shaver, M. D. Richardson,* J. H. McCalla, D. E. Karcher, and P. J. Berger

ABSTRACT

Bermudagrass [*Cynodon dactylon* (L.) Pers.] is one of the most widely used turfgrasses in the southern region of the USA and is also grown extensively in other tropical and subtropical regions around the world. The development of improved seeded cultivars has stimulated new research into best management practices to produce a high quality bermudagrass stand from seed. Dormant seeding has been used for establishing cool-season turfgrasses and may be beneficial for the early establishment of seeded bermudagrass cultivars. The objective of this study was to assess the effects of dormant seeding on the establishment of two seeded bermudagrass cultivars, Riviera and Princess 77. Two seeding rates [97.6 and 48.8 kg ha^{-1} pure live seed (PLS)] of each cultivar were seeded in February, March, April, and May of 2004 and 2005, with February and March considered dormant seeding dates. Date of first germination, seedling density, rate of establishment, and soil temperature data were collected for both years of the study. First germination of dormant-seeded plots was observed on 22 Apr. 2004 and 11 Apr. 2005 when soil temperatures were 13.6 and 16.2°C, respectively. Princess 77 germinated earlier than Riviera in both years of the study. Seeding date, cultivar, and seeding rate affected seedling density. Dormant-seeded plots reached full coverage as fast as or faster than traditional seeding dates in both years of the study, demonstrating that dormant seeding can be effectively used to establish bermudagrass from seed.

Bermudagrass is one of the most widely-used turfgrasses in tropical and subtropical regions of the world. Most of the cultivars that are used in intensively-managed turfgrass situations are sterile hybrids that must be established by vegetative propagation. Early attempts at developing cultivars of bermudagrass that could be propagated by seed had limited success in relation to improved turfgrass quality. 'Numex Sahara' and 'Sonesta' bermudagrass were two of the first improved seeded cultivars to be released (Rodgers, 2003). In the 1986 National Turf Evaluation Program (NTEP) bermudagrass test, Numex Sahara and Sonesta produced inferior turfgrass quality ratings compared with the vegetative standards (Morris, 1993). However, in the 1997 NTEP bermudagrass test, Princess 77 and Riviera were the first seeded bermudagrass cultivars to meet the quality standards of the top-performing vegetative cultivars (Morris, 2002). Riviera and Princess 77 are more uniform and display enhanced color, texture, and density compared with older-seeded bermudagrass cultivars.

Much of the early research on seeded bermudagrass focused on the effects of seeding rate and seeding date on turfgrass establishment and seedling winter survival. Musser and Perkins (1969) stated that the number of plants per unit area is the primary factor to consider when selecting a seeding rate to establish a stand of bermudagrass, especially in competition with weeds. They suggested a seeding rate of 97.6 kg ha^{-1} PLS which is approximately 38 471 seeds m^{-2}. This is in contrast with recent recommendations, where seeding rates of 12.2 to 24.4 kg ha^{-1} PLS have been shown to increase stolon fitness and subsequent first-year winter survival of bermudagrass in the transition zone (Munshaw et al., 2001). Patton et al. (2004) also demonstrated that bermudagrass establishment was not increased with seeding rates higher than 49 kg ha^{-1}, and that no differences in turfgrass coverage were seen between seeding rates higher than 12 kg ha^{-1}, 42 d after seeding. The impact of seeding rate on establishment and winter survival of seeded bermudagrass is obviously important, but there are no clear trends among previous research that demonstrate an advantage of a specific seeding rate (Patton et al., 2004; Philley and Krans, 1998; Richardson et al., 2004).

Traditionally, late spring or early summer plantings have been recommended for bermudagrass establishment because the environmental conditions most favorably match the needs for germination and growth of bermudagrass (Johnson and Thompson, 1961; Madison, 1971). Ahring et al. (1975) demonstrated that when 'Arizona Common' bermudagrass was seeded after 9 May in Oklahoma, greater freeze injury occurred the winter following seeding compared with earlier seeding dates. Musser and Perkins (1969) agreed that late planting dates generally do not provide sufficient time for warm-season grasses to achieve adequate establishment before temperatures reach undesirable levels. Furthermore, Blaser et al. (1956a, 1956b) reported that establishment rates were dependent on seeding date, mainly due to the effects of temperature on germination time and initial seedling growth. Richardson et al. (2004) reported that seeding date had a significant effect on first-year winter survival, in that earlier seeding dates (April and May) had much higher winter survival than later (June or July) plantings. These studies and others (Philley and Krans, 1998) have clearly shown that bermudagrass should be established as early as possible in the spring to decrease the potential for winter injury.

Although not as common as traditional seeding, dormant seeding has been used for establishing cool-season turfgrasses (Ross, 2003). Dormant seeding refers to planting seed when soil temperatures are outside the normal range for germination (Reicher et al., 2000). While work has been done on dormant seeding of cool season turfgrasses (Green et al., 1974; Reicher et al.,

B.R. Shaver, M.D. Richardson, J.H. McCalla, and D.E. Karcher, Dep. of Horticulture; and P.J. Berger, Dep. of Men's Athletics, Univ. of Arkansas, Fayetteville, AR 72701. Received 6 Feb. 2006. *Corresponding author (mricha@uark.edu).

Published in Crop Sci. ■:■–■ (2006).
■
doi:10.2135/cropsci2006.02-0078

677 S. Segoe Rd., Madison, WI 53711 USA

Abbreviations: PLS, pure live seed.

2000; Ross, 2003), limited information is available on the effects of dormant seeding warm-season grasses such as bermudagrass. In the only published study conducted to date, Green et al. (1974) concluded that bermudagrass was not suitable for dormant, winter seeding and poor stands were observed in the summer following establishment. However, there have been no other documented attempts at using dormant seeding to establish bermudagrass. Preliminary observations at the University of Arkansas demonstrated that plots seeded in February and March (dormant-seeded) germinated earlier and established faster than plots seeded in April and May (Richardson, 2003, unpublished data), which is the typical time period to seed bermudagrass in Arkansas. These initial observations suggest that bermudagrass could be planted in the late winter and still germinate and establish successfully. The objectives of this study were to determine the effects of seeding date (dormant vs. spring), seeding rate, and cultivar on the establishment of bermudagrass in a transition zone environment.

MATERIALS AND METHODS

A field study was conducted in 2004 and 2005 at the University of Arkansas Agricultural Experiment Station in Fayetteville, AR, to assess the effects of dormant seeding on the establishment of two seeded bermudagrass cultivars, Riviera and Princess 77. The soil at the site is a Captina silt loam (fine-silty, siliceous, active, mesic Typic Fragiudults) with an average pH of 6.2. The area selected for the 2004 study was initially planted to 'Zenith' zoysiagrass (*Zoysia japonica* Steud.) during the 2003 growing season. The zoysiagrass was eradicated with two sequential applications of glyphosate (3.36 kg a.i. ha^{-1}) during the early fall of 2003. This approach provided an experimental area that was similar to a dormant grass but allowed data collection on seedling germination, growth, and establishment to occur in the absence of turfgrass recovery the following spring. For the 2005 study, the experimental area was developed in a similar manner, except the original turfgrass stand was Riviera bermudagrass established during the 2004 growing season and eradicated with similar applications of glyphosate in the fall of 2004.

Plots were seeded with either Princess 77 (Seeds West, Inc., Maricapa, AZ) or Riviera (Johnston Seed Co., Enid, OK) bermudagrass at two different seeding rates, 48.8 and 97.6 kg ha^{-1} PLS. During both years of the study, fresh seed lots from the current year were used. All cultivars and seeding rates were seeded near the 15th of each month from February through May in both years, with February and March considered dormant planting dates and April and May considered traditional planting dates. Treatments were arranged as a $2 \times 2 \times 4$ factorial of cultivar, seeding rate, and seeding date.

Before seeding, each plot was scarified using a vertical mower (Graden Industries, Campbellfield, VIC, Australia) to a depth of 13 mm and the debris was removed from each plot. Seed was applied using a drop spreader (Gandy Company, Owatonna, MN). After applying the seed, the plots were topdressed with 6 mm of dry sand. Weed control was achieved by hand removal during the germination phase, but MSMA (monosodium methylarsonate) was applied at 1.12 kg ha^{-1} a.i., as needed, once seedlings were a minimum of 2 wk old (McCalla et al., 2004).

For the 2004 study, two soil temperature data loggers (HOBO Temp, Onset Computer Corp., Bourne, MA) were placed in the plot area at the beginning of the study to record soil temperatures at a 2.54-cm depth. Soil temperature data were collected every hour for 120 d starting on the date of the first seeding treatment in February. For the 2005 study, soil temperature data was recorded in a similar manner, except one soil temperature data logger (HOBO H8 4-Channel Outdoor/Industrial Logger, Onset Computer Corp., Bourne, MA) with four replicate soil probes (HOBO Soil temperature sensor, TMCx-HD, Onset Computer Corp., Bourne, MA) was used to record soil temperature data at the 2.54-cm depth. Soil temperature responses to day of year were fitted to linear regression equations using the SAS general linear models program (SAS Institute, Cary, NC).

Date of first germination was recorded for each plot. At ≈2 wk after germination within each plot, seedling counts were made to assess establishment vigor of the various treatments. Small rings were made from 7.6-cm-diam. pipe and randomly tossed four times into each plot. The number of bermudagrass seedlings were counted in the ring for each toss and averaged for the entire plot. Data were converted to seedlings dm^{-2}. Seedling counts were collected two times per week for 2 wk following germination, and an average seedling density was calculated for each treatment.

Beginning 2 wk after initial germination, digital images were collected from all plots and analyzed to determine turfgrass coverage (Richardson et al., 2001; Karcher and Richardson, 2005). Digital images were obtained with an Olympus C3030Z (Olympus Optical Co., London, UK) housed in an enclosed box fitted with four halogen light bulbs designed to provide uniform light coverage (Ikemura, 2003).

In late April 2005, an emergence of bermudagrass seedlings was observed across the entire plot area, including plots that had not yet been seeded (May plots), in plots that never received seed (nonseeded checks), and in border areas around the plots. It is assumed that these seedlings resulted from residual hard seed (Charles Taliaferro, Oklahoma State University, 2005, personal communication) remaining from the Riviera planting the previous year since this experimental area had been fumigated with methyl bromide before planting the Riviera. The seedlings were uniformly emerging (1.7 seedlings dm^{-2}) in plots that had not been seeded and we assume they were also emerging at the same density in plots that had already emerged (February, March, and April). At the time of this emergence, data on germination date and seedling density had already been collected from the February, March, and April plantings and was therefore not compromised by the emergence of the seedlings. However, since this emergence occurred before the May treatments were seeded, data on germination date and seedling density was not collected for the May seeding date treatments. On the basis of the uniformity of germination from this residual seed, it was determined that the studies integrity was not compromised and we could collect data on establishment in all plots, with the assumption that the residual seed contribution was minimal and similar in all plots.

The experimental design was a randomized complete block with four replications of each treatment and a plot size of 1.8 by 2.4 m. All data were analyzed by ANOVA procedures and mean separation tests were conducted using Fisher's Protected LSD ($P = 0.05$) (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The initial data analysis revealed there were significant year × treatment interactions for most of the data collected and data were subsequently analyzed by year. Analysis of variance for both 2004 and 2005 indicated

Table 1. Analysis of variance, testing the main effects and interactions of bermudagrass cultivar, seeding date, and seeding rate on turfgrass cover, germination date, and seedling density (2004 data).

Source	Turfgrass cover					Germination date	Seedling density
	19 May	3 June	16 June	23 June	1 July		
Rep.	NS†	NS	NS	*	*	NS	NS
Cultivar (C)	NS	NS	NS	NS	NS	***	***
Date (D)	**	***	***	***	***	***	**
Rate (R)	NS	NS	NS	NS	***	NS	**
C × D	NS	NS	NS	NS	NS	***	NS
C × R	NS	NS	NS	*	NS	NS	NS
D × R	NS	NS	NS	*	*	NS	NS
C × D × R	NS	NS	NS	NS	NS	NS	NS

* Significant *F* test at the 0.05 level of probability.
** Significant *F* test at the 0.01 level of probability.
*** Significant *F* test at the 0.001 level of probability.
† NS, not significant at the 0.05 level of probability.

that seeding date had a significant effect on turfgrass cover for all evaluation dates in 2004 (Table 1) and all but the last evaluation date in 2005 (Table 2). Similar trends in turfgrass establishment were seen in both the 2004 and 2005 trials (Fig. 1). In 2004, February and March seeding date treatments produced similar turfgrass cover on all evaluation dates (Fig. 1). April treatments produced less cover than March on all evaluation dates except the last when February, March, and April treatments were at or near 100% turfgrass cover (Fig. 1). The May seeding date had less turfgrass cover on all evaluation dates including 1 July 2004 when all other treatments were at or near 100% turfgrass cover (Fig. 1).

In 2005, differences in turfgrass cover were not seen between February and March seeding dates on any evaluation date, while the April seeding date had less turfgrass cover than the February and March dates on the first evaluation date only (Fig. 1). However, as seen in 2004, a May seeding date resulted in less turfgrass cover for all evaluation dates in 2005, with the exception of the last evaluation date when all plots were at or near 100% turfgrass cover (Fig. 1). The most evident difference between the 2 yr in terms of turfgrass coverage is that the May seeding date failed to reach 100% coverage before evaluations ended in 2004, while in 2005, the May seeding date was able to achieve 100% turfgrass coverage, although slower than the other seeding date treatments (Fig. 1).

These findings were similar to those of Patton et al. (2004) in that earlier seeding dates established as quickly as later seeding dates and had similar coverage at the end of the summer. Hensler et al. (1999) found that April and May seeding dates produced similar if not greater root weight and stolon counts compared with mid- and late-summer seeding dates, again indicating that spring seeding dates produced a full cover as fast or faster than later seeding dates. It is important to point out that in these previous studies, the earliest seeding dates tested were early April, while in our study early April was considered one of the later seeding dates. However, trends in establishment rates are similar between studies; earlier seeding dates lead to enhanced turfgrass coverage compared with later seeding dates.

Seeding rate only had a significant effect on turfgrass cover for one evaluation date in 2004 (Table 1) and one evaluation date in 2005 (Table 2). Patton et al. (2004) demonstrated that bermudagrass establishment was not increased with seeding rates higher than 49 kg ha^{-1}, and that no differences in turfgrass coverage were seen between seeding rates higher than 12 kg ha^{-1}. The present study would also suggest that high seeding rates are not required to obtain fast turfgrass coverage with an improved seeded bermudagrass.

In 2005, cultivar had a significant effect on turfgrass coverage for five out of seven evaluation dates (Table 2), with Princess 77 having a higher turfgrass establishment rate in 2005 compared with Riviera (Fig. 2). However, the greatest difference in turfgrass coverage between cultivars was only 8% on the 25 May evaluation date in 2005, while there were no differences among cultivars in terms of turfgrass cover for 2004 (Table 1). Although these differences were statistically significant,

Table 2. Analysis of variance, testing the main effects and interactions of bermudagrass cultivar, seeding date, and seeding rate on turfgrass cover, germination date, and seedling density (2005 data).

Source	Turfgrass cover					Germination date	Seedling density
	20 May	25 May	1 June	8 June	15 June		
Rep.	NS†	NS	*	*	NS	NS	NS
Cultivar (C)	NS	**	*	*	*	***	***
Date (D)	***	***	***	***	NS	***	***
Rate (R)	*	NS	NS	NS	NS	NS	*
C × D	NS	NS	NS	NS	NS	***	NS
C × R	NS	NS	NS	NS	NS	NS	NS
D × R	NS	NS	NS	NS	NS	NS	NS
C × D × R	NS	NS	NS	NS	NS	NS	NS

* Significant *F* test at the 0.05 level of probability.
** Significant *F* test at the 0.01 level of probability.
*** Significant *F* test at the 0.001 level of probability.
† NS, not significant at the 0.05 level of probability.

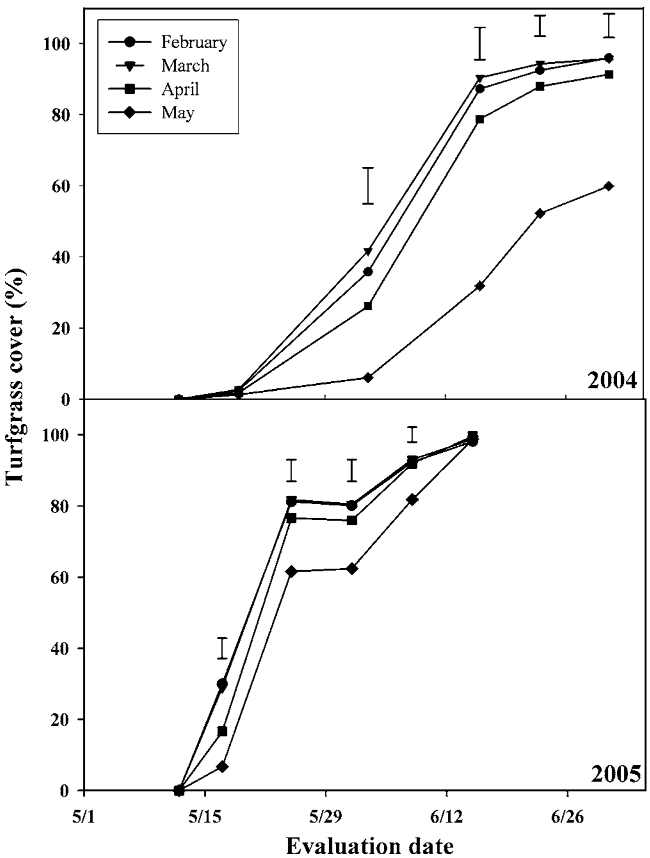

Fig. 1. Percentage turfgrass cover of bermudagrass as affected by various seeding dates for the 2004 and 2005 trial. The LSD bars can be used to compare cover at each evaluation date (P = 0.05).

they would have little practical effect on turfgrass establishment rates and should not be used as a decision point for cultivar selection.

In 2004 and 2005, there was a significant cultivar and date main effect and cultivar × seeding date interaction on germination date (Tables 1, 2). For both years, Princess 77 germinated ≈7 d earlier in February and March plots compared with Riviera (Fig. 3). This cultivar effect might be attributed to the fact that Riviera was seeded

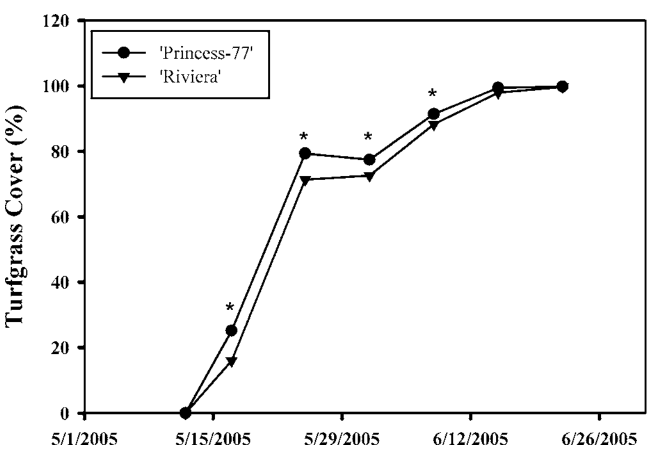

Fig. 2. Percentage turfgrass cover of bermudagrass as affected by cultivar in 2005. Statistical differences (P = 0.05) between cultivars are indicated by *.

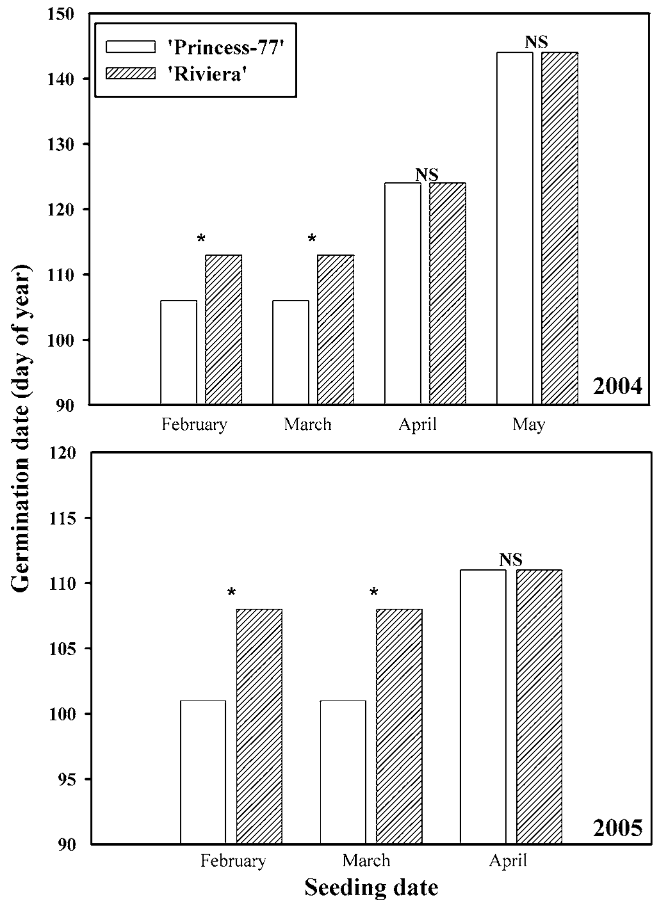

Fig. 3. Germination date (day of year), as affected by cultivar and seeding date in 2004 and 2005. Statistical differences among cultivars are indicated by * (significant at P = 0.05) or NS (not significant).

as a coated, hulled seed while Princess 77 was seeded as a noncoated, hulled seed. Hickey and Engelke (1983) reported a slight suppression of seedling emergence of hulled bermudagrass seed when treated with a seed coating. The cultivar effect was not seen for April and May seeding dates in 2004 or the April seeding date in 2005 (Fig. 3) as both cultivars displayed germination on the same day for those months. As soil temperatures increased at the later seeding dates, the seed coating was likely broken down at a faster rate and no longer affected germination of the Riviera.

Seeding date had a significant effect on seedling density for both 2004 (Table 1) and 2005 (Table 2). In 2004, the March seeding date had higher seedling density compared with other seeding dates which were not different (Fig. 4). However, in 2005, plots seeded in February had higher seedling density than those seeded in March, which had a higher seedling density than those seeded in April (Fig. 4). Although the reason for these differences is currently unclear, it is apparent that dormant seeding had no negative effect on seed viability and seedling stand counts. In fact, dormant-seeded plots had the highest seedling stand counts in both 2004 and 2005 (Fig. 4).

Seeding rate had a significant effect on seedling density in both years of the trial (Tables 1, 2) with the higher (97.6 kg ha^{-1}) seeding rate having greater

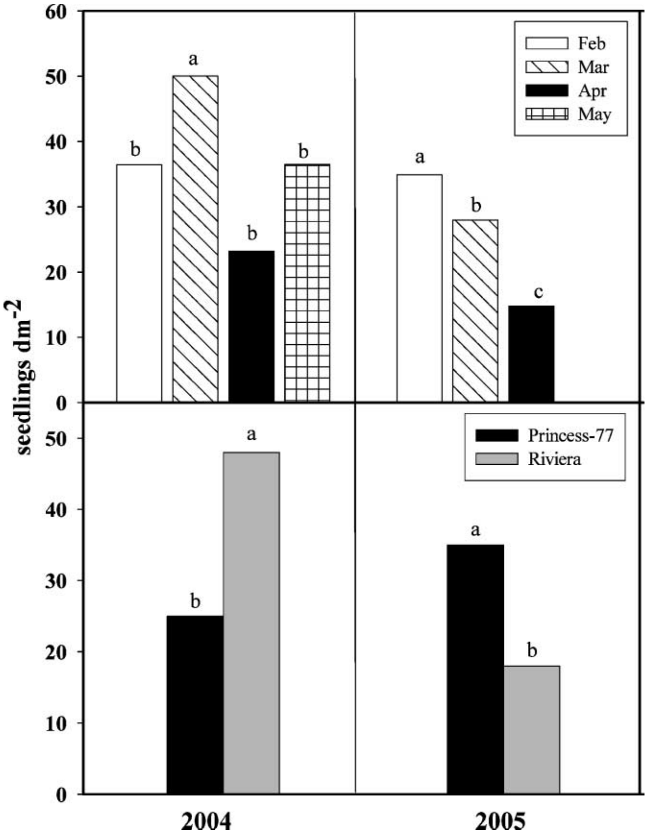

Fig. 4. Seedling density as affected by seeding dates (top graphs) and cultivar (bottom graphs). Letters on top of each bar indicate significant differences in seedling density among main effects within 2004 and 2005.

numbers of seedlings dm^{-2} compared with the lower (48.8 kg ha^{-1}) seeding rate (data not shown). However, in both years, the increase in seedling density did not approach the two-fold increase in seed planting density. While higher seeding rates resulted in higher seedling stand counts, these increases had no effect on turfgrass establishment rate (Tables 1, 2). These findings agree with those of Patton et al. (2004), in that seeding rates $>$ than 49 kg ha^{-1} had no effect on turfgrass establishment rate.

Cultivar had a significant effect on seedling density in both years of the study. However, the results were not consistent between years. In 2004, Riviera produced a greater number of seedlings dm^{-2} than did Princess 77, while Princess 77 exhibited an increase in seedling density compared with Riviera in 2005 (Fig. 4). It is unclear at this time why cultivar differences existed during the 2 yr of the study, but it could be attributed to the use of separate seed lots from 2004 to 2005 since the current year's seed was used for both years of the study.

In 2004, germination of Princess 77 was observed in February- and March-seeded plots on 15 April, when mean soil temperatures were 15.5°C, while plots seeded to Riviera displayed germination on 22 April when soil temperatures had reached 16.5°C (Fig. 5). In 2005, dormant-seeded plots of Princess 77 first germinated on 11 April when soil temperatures were 15.0°C, while plots seeded to Riviera germinated on 18 April when soil temperatures had reached 15.5°C (Fig. 5). It has been suggested previously that soil temperatures from 20 to 35°C were required for germination of hulled bermudagrass and other warm season turfgrasses (Beard, 1973; McCarty, 2005). Soil temperatures at germination for dormant seeding dates were below previously suggested soil temperature requirements for bermudagrass. These results demonstrate that bermudagrass can germinate at lower soil temperatures than was previously described. These findings more closely resemble what Fidanza et al. (1996) reported with crabgrass emergence, another C4 grass species. In that study, crabgrass emergence was observed when soil temperatures were as low as 10.4°C. However, Fidanza et al. did report a major emergence period occurring when soil temperatures ranged from 19.5 to 24.9°C, which would more closely match previous recommendations for C4 grasses. In this study, germination was recorded as date of first germination, and not recorded across time as with previous studies of C4 plants (Fidanza et al., 1996). While bermudagrass germination in this study was seen when soil temperatures were as low as 15.0°C (Fig. 5), more work is needed to determine the minimal and optimum germination temperature range for seeded bermudagrass.

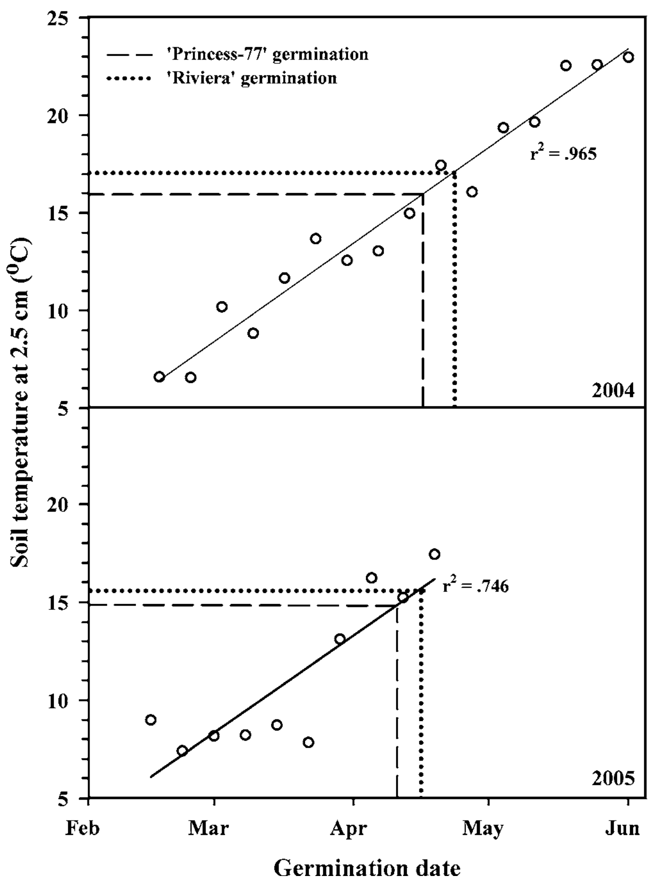

Fig. 5. Average weekly soil temperatures (open circles) and germination dates for February and March plantings of 'Princess 77' and 'Riviera' bermudagrass in Fayetteville, AR, in 2004 and 2005. Soil temperature (2.54 cm) was regressed over time to predict soil temperature at germination.

CONCLUSIONS

Dormant seeding of bermudagrass proved to be a successful means of establishing both Princess 77 and Riviera bermudagrasses. Germination of bermudagrass was seen while soil temperatures were as low as 15.0°C, indicating that bermudagrass germination can occur at temperatures lower than what has previously been reported. Furthermore, dormant-seeded plots displayed full turfgrass cover as fast of faster than traditional seeding dates for both years of the study.

Collectively, these studies demonstrate that improved seeded bermudagrass cultivars can be successfully established by seeding in late winter in northwest Arkansas. This could be beneficial for turfgrass managers, as February and March workloads are often lighter due to a reduction in use of the turf. Seeding during this time of the year would give turf managers a larger window for repair or establishment projects and could reduce the amount of time spent on such projects during the growing season. Further understanding of exactly how early in the year bermudagrass could be seeded and still provide acceptable results would be beneficial.

REFERENCES

Ahring, R.M., W.W. Huffine, C.M. Taliaferro, and R.D. Morrison. 1975. Stand establishment of bermudagrass from seed. Agron. J. 67:229–232.

Beard, J.B. 1973. Turfgrass science and culture. Prentice Hall, Englewood Cliffs, NJ.

Blaser, R.E., T. Taylor, W. Griffith, and W. Skirdle. 1956a. Seedling competition in compounding forage seed mixtures. Agron. J. 48: 118–123.

Blaser, R.E., T. Taylor, W. Griffith, and W. Skirdle. 1956b. Seedling competition in establishing forage plants. Agron. J. 48:1–6.

Fidanza, M.A., P.H. Dernoeden, and M. Zhang. 1996. Degree-days for predicting smooth crabgrass emergence in cool-season turfgrasses. Crop Sci. 36:990–996.

Green, J.T., H.D. Perry, J.M. Woodruff, and R.E. Blaser. 1974. Suitability of cool- and warm-season species for dormant winter seedings. p. 557–568. *In* E.C. Roberts (ed.) Proc. Int. Turfgrass Res. Conf., 2nd, 19–21 June 1973. ASA and CSSA, Madison, WI.

Hensler, K.L., M.D. Richardson, and J.R. Bailey. 1999. Implications of seeded bermudagrass planting date and morphology on cold tolerance. p. 69–71. *In* J.R. Clark and M.D. Richardson (ed.) Horticultural Studies 1998. Res. Ser. 466. Ark. Agric. Exp. Stn., Univ. of Ark. Div. of Agric., Fayetteville, AR.

Hickey, V.G., and M.C. Engelke. 1983. Effect of experimental seed coating on bermudagrass seed germination. Texas Turf. Res. 4170: 129–130.

Ikemura, Y. 2003. Using digital image analysis to measure the nitrogen concentration of turfgrasses. M.S. thesis. Univ. of Arkansas, Fayetteville.

Johnson, C.M., and W.R. Thompson. 1961. Fall and winter seeding of lawns. Mississippi Farm Res. 24:4.

Karcher, D.E., and M.D. Richardson. 2005. Batch analysis of digital images to evaluate turfgrass characteristics. Crop Sci. 45:1536–1539.

Madison, J.H. 1971. Principles of turfgrass culture. Van Nostrand Reinhold Co., New York.

McCalla, J.H., M.D. Richardson, D.E. Karcher, and J.W. Boyd. 2004. Tolerance of seedling bermudagrass to postemergence herbicides. Crop Sci. 44:1330–1336.

McCarty, L.B. 2005. Best golf course management practices. 2nd ed. Pearson Education, Upper Saddle River, NJ.

Morris, K.N. 1993. National Turfgrass Evaluation Program. 1986 National Bermudagrass Test. NTEP No. 93–1. USDA, Beltsville, MD.

Morris, K.N. 2002. National Turfgrass Evaluation Program. 1997 National Bermudagrass Test. NTEP No. 02–7. USDA, Beltsville, MD.

Munshaw, G.C., D.W. Williams, and P.L. Cornelius. 2001. Management strategies during the establishment year to enhance production and fitness of seeded bermudagrass stolons. Crop Sci. 41:1558–1564.

Musser, H.B., and A.T. Perkins. 1969. Guide to planting. p. 447–490. *In* A.A. Hanson and F.V. Juska (ed.) Turfgrass science. Agron. Monogr. 14. ASA, Madison, WI.

Patton, A.J., G.A. Hardebeck, D.W. Williams, and Z.J. Reicher. 2004. Establishment of bermudagrass and zoysiagrass by seed. Crop Sci. 44:2160–2167.

Philley, W.H., and J.V. Krans. 1998. Turf performance of seeded bermudagrass cultivars. Golf Course Manage. 66(11):62–66.

Reicher, Z.J., C.S. Throssell, and D.V. Weisenberger. 2000. Date of seeding affects establishment of cool-season turfgrasses. HortScience 35:1166–1169.

Richardson, M.D., D.E. Karcher, P. Berger, and J.W. Boyd. 2004. Utilizing improved seeded bermudagrasses on transition-zone sports fields. Acta Hortic. 661:369–374.

Richardson, M.D., D.E. Karcher, and L.C. Purcell. 2001. Quantifying turfgrass cover using digital image analysis. Crop Sci. 41:1884–1888.

Rodgers, C. 2003. You've come a long way, bermuda. Golf Course Manage. 71(8):91–95.

Ross, K.J. 2003. Dormant seeding: A different approach. Golf Course Manage. 71(9):70–73.

Steel, G.D., and J.H. Torrie. 1980. Principles and procedures of statistics. 2nd ed. McGraw-Hill, New York.