Establishment and Maintenance During Establishment of Hybrid Bluegrass (*P. arachnifera* Torr. × *P. pratensis* L.) in the Transition Zone

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Abstract. The transition zone is one of the hardest places to maintain high-quality turfgrasses, and the overall research objective was to determine best management practices to establish new turf cultivars in this zone. Hybrid bluegrasses (*P. arachnifera* Torr. × *P. pratensis* L.) have been bred for heat and drought tolerance and may offer a new alternative to other turfgrasses. The specific cultivars examined in this research were ‘Thermal Blue®’ and ‘Dura Blue®’. Experiments were conducted during 2003, 2004, and 2005 in Knoxville, TN. ‘Thermal Blue’ was seeded at 50, 100, 150, 200, and 250 kg·ha⁻¹ of seed. ‘Thermal Blue’s’ ideal seeding rate was between 100 and 150 kg·ha⁻¹ of seed in 2003 and 50 kg·ha⁻¹ in 2004. ‘Thermal Blue’ was also seeded in January, April, July, and September of each year with 100 kg·ha⁻¹ of seed. All seeding dates took ≈11 months to become well established. However, July seeding produced poor turf quality (less than 6) and was the only seeding date deemed unacceptable. ‘Thermal Blue’ and ‘Dura Blue’ were fertilized with ammonium nitrate at 100, 200, and 300 kg N/ha/year and urea formaldehyde at 200 and 300 kg N/ha/year starting in March of each year. These treatments were maintained at 2-, 3.5-, and 5-cm mowing heights. ‘Thermal Blue’ had higher quality evaluations and produced more clippings than ‘Dura Blue’ throughout the year. Higher fertility regimens increased quality evaluations in April but decreased quality evaluations in October. Increasing the mowing height improved turf quality and decreased biomass production for both grasses. A proposed optimum method for establishment included seeding ‘Thermal Blue’ in April at 150 kg·ha⁻¹ and fertilizing with 300 kg·ha⁻¹ of nitrogen and then mowing at 5-cm height. ‘Thermal Blue’ and ‘Dura Blue’ are adapted for the transition zone, but summer heat stress may cause turf quality decrease in the fall.

Kentucky bluegrass (*Poa pratensis* L.) has been attempted to be grown in the transition zone; however, growing and maintaining this species throughout the year in this area can be difficult (Teuton et al., 2007). High humidity and high temperatures associated with summer and droughty soil conditions are often too stressful for Kentucky bluegrass to thrive (Shearman, 1999). Diseases such as rust (*Puccinia graminis* Persoon subsp. *graminicola* Urban) and dollar spot (*Sclerotinia homoeocarpa* Bennett) can cause injury and a reduced stand in Kentucky bluegrass (Landschoot and Park, 1997; Wang and Huang, 2004).

Recently, the Scotts Company (Maryville, OH) released ‘Thermal Blue’ and ‘Dura Blue’ Kentucky bluegrasses. These hybrid bluegrasses (*P. arachnifera* Torr. × *P. pratensis* L.) are interspecific hybrids of Texas bluegrass (*P. arachnifera* Torr.) and traditional Kentucky bluegrass. These hybrid bluegrass

cultivars were bred for having the heat and drought tolerance of Texas bluegrass and the desirable turfgrass quality of Kentucky bluegrass (Abraham et al., 2004). Previous research has shown these turf cultivars have potential for use in the transition zone (Su et al., 2008; Teuton et al., 2007) and that these hybrids may impart more heat tolerance than actual drought tolerance (Abraham et al., 2008; Su et al., 2007).

Kentucky bluegrass is widely used in the transition zone and in the colder northern climates where optimum seeding rates, nitrogen fertility, and mowing heights are used (Beard, 1973; Bredakis, 1959; Jagschitz and Skogley, 1965; Juska and Hanson, 1961; Juska et al., 1955; Kuhn and Kemp, 1939; Skogley and Ledebauer, 1968). In general, Kentucky bluegrass should be seeded between 50 to 100 kg·ha⁻¹, which produces three to eight seed per square centimeter (Beard, 1973). However, many of the turfgrass breeders and developers have had problems with low seed yield, low germination rates, and poor seedling vigor in many of the new hybrid cultivars (Jim Frelich, personal communication). A literature search revealed minimal published information on

seed establishment and maintenance of the hybrid bluegrasses. The objectives of these experiments were to: 1) determine optimal seeding rates; 2) establish the correct seed timing; and 3) investigate the interaction of mowing height and fertility requirements for ‘Thermal Blue’ and ‘Dura Blue’. These objectives are all specifically oriented toward the transition zone as previously described.

Materials and Methods

General procedures. Field experiments were conducted from 2003 to 2005 at the Plant Science Farm near Knoxville, TN. The soil type was a Sequatchie loam (fine-loamy, siliceous, thermic Humic Hapudult), which was 39% sand, 46% silt, and 15% clay with 1.0% organic matter and a pH of 6.5. Study areas were treated with the soil fumigant Dazomet (tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione; BASF, Research Triangle Park, NC) at 390 kg a.i./ha on 23 Aug. 2003 and 27 Aug. 2004 to reduce weed and soilborne disease pressure. Dazomet was tilled into the soil immediately after application and the area was irrigated with 0.5 to 1.0 cm of water three times per day for 7 d. Study areas were tilled 14 d after Dazomet application to ensure complete release of fumigant gasses before seeding grasses.

‘Thermal Blue’ and ‘Dura Blue’ were evenly seeded at 100 kg·ha⁻¹ unless otherwise stated and incorporated into the soil using a handheld, spring tooth rake. Germination percentages and relative seed sizes were not determined. Seeding occurred on 29 Sept. 2003 and 25 Sept. 2004 unless otherwise stated. Irrigation was applied on an as-needed basis to establish and maintain a high-quality turfgrass. Water need was based on the need for 2 cm of rainfall/irrigation per week, and the average number of irrigations per week was 1.3 times of 0.75 cm of water per irrigation applied through overhead sprinklers. Nitrogen fertilization was applied at 25 kg N/ha/month (as ammonium nitrate) on newly seeded areas from September to December. Supplemental fertilization with 50 kg·ha⁻¹ of phosphorus (P) and potassium (K) using triple superphosphate (0-45-0) and potassium chloride (0-0-60) was applied at seeding. Spring fertilization included 49 kg N/ha on 1 Mar. with 25 kg N/ha applied every 6 weeks thereafter until the termination of the study unless otherwise noted. Fertilization was with a 29N-1.3P-3.3K analysis commercial fertilizer unless otherwise stated. All studies were mowed twice per week from 15 Oct. to 1 Jan. and again from 15 Mar. to the termination of each study. Times of seeding and seeding rate studies were mowed at 5-cm height and were only conducted with ‘Thermal Blue’ as a result of limited seed availability of ‘Dura Blue’. Oxadiazon [3-(2,4-dichloro-5-{1-methylethoxy}phenyl)-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3H)-one] (Bayer Environmental Science, Research Triangle Park, NC) was applied at 2.2 kg a.i./ha on the first week of April each year for pre-emergence

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crabgrass and goosegrass control on all studies except the time of seeding study where plots were hand-weeded. All plots were 1.5 × 3 m, and all studies were arranged in a randomized complete block design with four replications; all studies were repeated.

Seeding rate. Effect of seeding rate was evaluated in two studies conducted in 2 separate years with both being seeded in September. The experimental design was a randomized complete block with four replications. ‘Thermal blue’ was seeded at 50, 100, 150, 200, and 250 kg seed/ha. Visual observations of turf quality and turf cover were recorded monthly for 11 months after seeding (MAS). Quality was based on color, density, uniformity, texture, and disease incidence or environmental stress effect and was visually evaluated on a scale of 1 to 9, with 1 being brown or dead turfgrass and 9 being ideal turfgrass (Skogley and Sawyer, 1992). A quality standard of 6.5 was the minimum acceptable turfgrass quality evaluation. A quality score of 6 is often considered to be minimally acceptable, but we selected 6.5 as a level that more discerning turf professionals would consider to be a more desirable target in our particular geography. Percent cover was visually evaluated on a scale of 0 to 100, with 0 being no turfgrass and 100 being totally covered by turfgrass.

Time of seeding. ‘Thermal Blue’ was planted in September, January, April, and July in two studies. The first seeding each year for that experiment was in September. The objective was to establish the best time of year for planting. The research used a randomized complete block design with four replications. Glyphosate [N-(phosphonome thyl)glycine; Monsanto Company, St. Louis, MO] was applied as a 2% solution 2 weeks before seeding for control of emerged weeds. All plots were lightly tilled (≈0.5-cm depth) the day of planting and seed was evenly broadcast and incorporated with a spring tooth rake. Plots were fertilized at planting as previously described and were monitored monthly for quality and percent cover for 11 to 12 MAS.

Fertility and mowing. Two cultivars and five fertility regimens were arranged in a factorial treatment design within a split-plot design with four replications and the study was repeated. ‘Thermal Blue’ and ‘Dura Blue’ were fertilized with ammonium nitrate at 100, 200, and 300 kg N/ha/year, which were applied at 8, 16, and 24 kg N/ha/month, and urea formaldehyde applied at 200 and 300 kg N/ha/year, which were applied at 66 and 100 kg N/ha in March, June, and September. Also, 50 kg-ha⁻¹ of P and K were applied as triple superphosphate and potassium chloride in March of each year. All fertilizer treatments were applied on approximately the 15th of each month. Mowing heights of 2, 3.5, and 5 cm that were 1 m wide were randomly superimposed as strip plots across each replication. Plots were mowed twice per week. Plots were visually evaluated for quality as previously described. Turfgrass clippings for each plot were collected each

month ≈15 d after fertilizer applications from March through December in a rear-discharge bag of a lawn mower. Dry weights of clipping samples were recorded after 4 d of forced-air drying at 65 °C. Although total plant biomass was not measured, we denoted that our clippings data served as an indirect measure of the plant biomass produced from that plot.

SAS Institute (1999) Proc Mixed was used to perform analysis of variance for turfgrass cover, quality, and clipping yield. All data were checked for equal variance and arcsine square root transformations were performed when necessary as determined by the Shapiro-Wilk statistic; however, untransformed means are presented for clarity. Main effects and all possible interactions were tested using appropriate expected mean square values as recommended by McIntosh (1983). Data were pooled across studies where possible. Means were separated using Fisher’s protected least significant difference at the 5% significance level or regressed using nonlinear regression models in Sigma Plot (Point Richmond, CA). Most data were fit to the exponential rise to maximum model, which fits the equation:

$$Y = a[1 - \exp(-b)x]$$

where y = the turf variable measured (such as quality or cover), a = inflection point of curve where data are changing most rapidly, and b = the rate of increase of y as affected by the independent variable (usually time). Each plot is shown regressed against a single variable such as seeding rate. The larger variable B, the faster the rise to maximum inflection point of Variable a.

Results and Discussion

Seeding rate. There were no differences in the ‘Thermal Blue’ percent cover between years; however, seeding rates, MAS, and their interaction (test for repeated measures) were significant. Therefore, data for percentage soil cover were pooled and regressed (Thornley and Johnson 1990). Seeding rates for ‘Thermal Blue’ fit ($r^2 = 0.99$) an exponential rise to the maximum equation (Fig. 1). Regression analysis indicated that ‘Thermal Blue’ seeded in September provided complete groundcover by March (5 MAS). This indicates that sod producers can seed at lower rates and still have a good cover by 5 MAS. Homeowners and turf professionals who want more rapid cover should use higher seeding rates, although if they waited, they could also obtain acceptable turf quality by the same time interval using lower seeding rates.

There were significant differences in ‘Thermal Blue’ turf quality among years, seeding rates, MAS, and their interactions. Data were separated by year and reanalyzed. In 2003, ‘Thermal Blue’ quality among seeding rates and MAS were significant, but in 2004, only MAS was significant. Therefore, seeding rate quality were separated in 2003 and pooled in 2004 and then regressed.

Fig. 1. ‘Thermal Blue’ percentage of soil cover using seeding rates from 50 to 250 kg-ha⁻¹ in Knoxville, TN, from 2003 and 2004. Regression line represents an average of all rates pooled to fit the exponential rise to maximum function. Individual seeding rates denoted in legend by different symbols.

Turf quality scores of seeding rates fit ($r^2 \geq 0.95$) an exponential rise to the maximum equation for both years (Fig. 2; 2004 data not shown). Regression output for Variable a were all greater than 7.4, but there was a different rate of increase in turf quality based on Variable b with lower seeding rates having slower development of turf quality in 2003. By 2 MAS in 2003, only seeding rates above 150 kg-ha⁻¹ were above the 6 turf quality level. However, ‘Thermal Blue’ quality continued to improve and by February (5 MAS), all seeding rates were 6 or greater (Fig. 2). By July (10 MAS), no difference could be ascertained from any of the seeding rates. In 2004, all turf quality scores 2 MAS and in all later evaluations were greater than 6.5 (data not shown). Differences in years may be the result of differing seed lots, in which seed weights play a large role in seedling germination and vigor (Larsen and Andreassen, 2004). However, no measurements were made directly of seed size or weight, so this is just a possibility.

Time of seeding. There were no differences in percent cover for ‘Thermal Blue’ between years for the time of seeding. However, MAS was significant, so data were pooled and regressed over time and ‘Thermal Blue’ fit ($r^2 = 0.90$) to an exponential rise to the maximum equation (Fig. 3). ‘Thermal

Fig. 2. ‘Thermal Blue’ turf quality scores from seeding rates from 50 to 250 kg-ha⁻¹ in Knoxville, TN, in 2003. Equations shown fit to exponential rise to maximum function.

Blue' percentage of cover did not depend on the time of year. One important observation from this study was that percentage of soil cover from July plantings decreased 7 to 8 MAS. This is a concern for planting these turfgrasses during this time of year, and this practice should be avoided if possible.

For some reason, 'Thermal Blue' took longer to completely cover the plot area in the time of seeding research than it did in the seeding rate research, although 100 kg·ha⁻¹ of seed/ha was used. Complete coverage took ≈11 MAS, which is too long for most turf professionals. We can provide no basis for this observation, although differences in seed vigor could be possible.

There were no differences in 'Thermal Blue' turf qualities between years for the seed timing. However, MAS, time of seeding, and their interaction were significant; therefore, data were separated and regressed over time. Time of seeding for 'Thermal Blue' fit a sigmoidal shaped curve ($r^2 \geq 0.86$) (Fig. 4). The differences in regression equations were the result of the January data, in which the seed lay dormant until the end of February before germination. This delay resulted in lower quality ratings up to 5 MAS (Fig. 4). However, the January seeding had the highest quality evaluations from 11 MAS. July seeding performed the worst with quality scores that remained below 6 for the several months. This may have been the result of seedling mortality in August and subsequent slow recovery.

Fertility and mowing heights. Cultivar, months, months by cultivar, months by height, and year by month by cultivar by fertility by mowing height were all significant for turf quality (analysis not shown). No interactions occurred among cultivar, fertility treatments, or mowing heights at any of the dates and therefore only the main effects of quality are discussed.

'Thermal Blue' had higher quality evaluations than 'Dura Blue' in April (Table 1). This was the result of 'Thermal Blue's' finer texture; however, both 'Dura Blue' and 'Thermal Blue' exhibited turf quality scores greater than 6.5. In July, there were no differences in turf quality between 'Dura

Blue' and 'Thermal Blue'. The slight decrease in quality of 'Thermal Blue' was the result of a slightly lighter green color during the summer. By October of each year, both grasses had fallen below a 6 quality score. This was mostly the result of the increased heat stress from July and August. However, both grasses were starting to recover by October. High temperatures (greater than 28 °C) are typical in Tennessee and the transition zone in July and August, and these environmental conditions were present during both years of this study.

Cultivars, month by cultivar, and month by height were all significant for clippings. Therefore, clippings data were separated by month and reanalyzed (analysis not shown). There were significant differences in turf clipping dry weights for cultivars, treatment, and mowing heights in April; mowing heights in July; and treatment and mowing heights in October. However, no interactions occurred among cultivar, treatments, or mowing heights at any of the dates and therefore only the main effects of biomass are discussed. 'Thermal Blue' produced 39 more kilograms per hectare of clipping dry weight/ha than 'Dura Blue' in April (Table 1). Overall, 'Thermal Blue' produced higher amounts of clippings and was the more aggressive of the two grasses. This also indicates that 'Thermal Blue' may have higher matt and thatch accumulation, which could lead to increased disease pressure (Teuton et al., 2007).

'Thermal Blue' and 'Dura Blue' responded similarly in dry weight for all of

the fertilizer regimens and turf quality differences could only be seen in April and October (Table 2). In April, ammonium nitrate at 300 kg N/ha produced the highest turf quality and urea formaldehyde at 200 kg N/ha produced the lowest quality. Although these evaluations were statistically different, the actual differences were small and all of acceptable turf quality. By October, turf quality had completely reversed. Urea formaldehyde at 200 kg N/ha had the highest quality score and

Fig. 4. 'Thermal Blue' turf quality scores when planted in January (○), April (●), July (▼), and September (■) in Knoxville, TN. Data pooled across two separate studies.

Table 1. 'Thermal Blue' and 'Dura Blue' turf quality and dry weights pooled over fertility, mowing heights, and years in Knoxville, TN, in 2004 and 2005.

Cultivar	April	July	Oct.
	Quality (1-9)		
Dura Blue	7.7	7.6	6.4
Thermal Blue	8.1	7.6	6.4
Least significant difference (0.05)	0.1	NS	NS
Cultivar	Dry weight (kg·ha ⁻¹)		
	April	July	Oct.
Dura Blue	78	143	53
Thermal Blue	117	170	51
Least significant difference (0.05)	7	NS	NS

NS = nonsignificant.

Table 2. 'Thermal Blue' and 'Dura Blue' turf quality and dry weights for fertility regimens pooled over cultivar, mowing height, and years in Knoxville, TN, in 2004 and 2005.

Fertility	kg N/ha	April	July	Oct.
		Quality (1-9)		
Ammonium nitrate	100	7.8	7.7	6.6
Ammonium nitrate	200	8	7.6	6.3
Ammonium nitrate	300	8.1	7.5	5.9
Urea formaldehyde	200	7.7	7.6	6.6
Urea formaldehyde	300	7.8	7.5	6.4
Least significant difference (0.05)		0.2	NS	0.4
Fertility	kg N/ha	Dry weight (kg·ha ⁻¹)		
		April	July	Oct.
Ammonium nitrate	100	90	149	51
Ammonium nitrate	200	104	160	52
Ammonium nitrate	300	109	166	50
Urea formaldehyde	200	91	150	52
Urea formaldehyde	300	95	155	58
Least significant difference (0.05)		NS	NS	NS

NS = nonsignificant.

Fig. 3. 'Thermal Blue' percentage of soil cover when planted in January, April, July, and September in Knoxville, TN. Data pooled across two separate studies.

ammonium nitrate at 300 kg N/ha had the lowest quality score. The reversal of turfgrass quality from spring to fall is presumably the result of increased summer heat stress and decreased rooting by the higher nitrogen (N) treatments (Badra et al., 2005; Bilgili and Acikgoz, 2005). Another possible explanation is the possible buildup of N in the case of the slow-release materials affecting the turf. There were no quality advantages in using slow-release (urea formaldehyde) over fast-release (ammonium nitrate) fertilizers. However, many turf professionals may choose to use slower-release fertilizers as a result of their longevity.

'Thermal Blue' and 'Dura Blue' produced approximately the same amount of clippings regardless of fertilizers used at all dates (Table 2). This indicates that a lower fertility rate using either fast- or slow-release fertilizers is acceptable and clipping yield is relatively the same. In previous research, kentucky bluegrass has been shown to have better turf quality and decreased weed pressure if clippings are returned to the turfgrass canopy (Heckman et al., 2000; Kopp and Guillard, 2002).

'Thermal Blue' and 'Dura Blue' responded identically in dry weight for all mowing heights and increased mowing heights improved turf quality (Table 3). In April and July, there was no difference in quality with 3.5- or 5-cm mowing heights, and the 2-cm mowing height had the lowest turf quality. However, there was little difference in these quality evaluations and all were acceptable. By October, the 3.5- and the 5-cm mowing heights were different but both were acceptable. However, the 2-cm mowing height had dropped below the 6 minimum quality score. This research indicates that 'Thermal Blue' and 'Dura Blue' should be maintained at 3.5 cm or greater.

'Thermal Blue' and 'Dura Blue' responded similarly for all mowing heights and increased mowing heights decreased their clipping yield (Table 3). April was the only evaluation date at which there were any statistical differences. Both grasses produced the most clippings at the lower height of cuts.

Conclusion

'Thermal Blue' should be seeded any time from September to April, because this timing gives adequate time for the seed germination and growth before the hot summer months. July seeding in the transition zone is not recommended. 'Thermal Blue' performed well in seeding trials; however, the addition of a small percentage of perennial ryegrass or turf-type tall fescue may decrease the time to reach the desired cover and quality and decrease the chance of erosion (Teuton et al., 2007).

Overall, seeding 'Thermal Blue' at 100 to 150 kg-ha⁻¹ would be ideal for most homeowners or turf professionals. Sod producers may consider using 50 kg-ha⁻¹ of seed to lower the seed cost because there was little difference in the amount of cover by 10

Table 3. 'Thermal Blue' and 'Dura Blue' turf quality and dry weights for mowing heights of 2-, 3.5-, and 5-cm mowing heights pooled over cultivar, fertility, and years in Knoxville, TN, in 2004 and 2005.

Mowing ht (cm)	April	July	Oct
	Quality (1-9)		
2	7.6	7.1	5.1
3.5	7.9	7.8	6.8
5	8	7.9	7.3
Least significant difference (0.05)	0.2	0.2	0.3
	Dry weights (kg-ha ⁻¹)		
	April	July	Oct
2	128	176	55
3.5	85	163	52
5	81	129	50
Least significant difference (0.05)	6	NS	NS

NS = nonsignificant.

MAS, and quality soon after seeding is not as important as with homeowners or golf courses.

Our studies indicate that 'Dura Blue' and 'Thermal Blue' are comparable in quality and clipping production. Also, higher mowing heights increase the quality scores and decrease the clippings produced for both grasses at the end of the year. Higher fertility regimens in the spring may increase the quality scores in that season. Based on this research, both 'Thermal Blue' and 'Dura Blue' will need appropriate maintenance to thrive and thus are not well suited for low-maintenance home lawn turf situations. They are slower to form a dense lush turf than tall fescues, which are more common in the transition zone (Teuton et al., 2007). Both require frequent mowing as a result of their aggressive growth habits, and dethatching will probably be required on a yearly basis. Irrigation will also be required in the transition zone, especially during summer heat stress. Both grasses are susceptible to the disease dollar spot and fungicide applications will be necessary to maintain a high-quality turf during the late summer and fall seasons.

Given the slow initial growth of these hybrid bluegrass cultivars, relevant future research topics include the use of grass seed blends to provide more rapid turf cover. More complete characterization of disease susceptibility and the effect of plant growth regulators would also be useful.

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