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Researchers at Kansas State University investigated 28 Kentucky bluegrass (*Poa pratensis* L.) cultivars and two hybrids (*P. arachnifera* Torr. x *P. pratensis*) for their potential to maintain acceptable quality with less water using wilt-based irrigation. The plots were well watered until the study began (above left). Thereafter, water was withheld until 50% or more of a plot displayed drought symptoms (above right). Results indicated that cultivars in Compact America and Mid-Atlantic groups likely have the greatest potential for maintaining acceptable visual quality with less water.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1921, the USGA has funded more than $40 million for research at universities. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Effects of Wilt-Based Irrigation on Visual Quality and Seasonal Water Applications on 30 Bluegrasses in the Transition Zone

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SUMMARY

With water for turfgrass irrigation becoming increasingly scarce, researchers at Kansas State University investigated 28 Kentucky bluegrass (*Poa pratensis* L.) cultivars and two hybrids (*P. arachnifera* Torr. x *P. pratensis*) for their potential to maintain acceptable quality with less water using wilt-based irrigation. Irrigation was applied when ≥50% of a plot exhibited wilt. Results include:

- Seasonal irrigation ranged from 9.2-17.7 inches over approximately 3.5 months (0.6-1.2 inches/week) among cultivars. Less water was applied to cultivars in Compact America and Mid-Atlantic phenotypic groups and the most to cultivars in the Common group.
- Days to wilt between irrigations ranged from 6.4-13.1 days among cultivars but was greatest in Compact America and Mid-Atlantic types. This provides estimates of irrigation frequency required to maintain these bluegrass cultivars at levels similar to this study, at least in the transition zone.
- Visual quality declined below "minimally acceptable" in all cultivars. The rate of decline varied from 8.1 to 44.8 days but was fastest in Common (10.4 days).
- Overall, visual quality averaged slightly below acceptable, which may be appropriate for low-maintenance roughs.
- Cultivars in Compact America and Mid-Atlantic groups likely have the greatest potential for maintaining acceptable visual quality with less water.

One of the most important challenges facing the golf and turf industry today is the increasingly limited supply of water for irrigation of turfgrasses. Consequently, water conservation and improving the resistance of turfgrasses to drought stress have become topics of major importance. In some regions, state and local drought restrictions may be imposed on superintendents with no regard for damage to golf properties. Nevertheless, golfers at private and public facilities express their displeasure when turfgrass quality is reduced during irrigation restrictions.

Kentucky bluegrass is commonly used on golf course roughs and fairways in the U.S. (8). Furthermore, roughs and fairways represent the greatest acreage of high quality turf on a golf course and often receive the greatest proportion of water. Kentucky bluegrass often goes dormant under drought conditions, which severely decreases its visual quality and function. Information is needed on cultivars of Kentucky bluegrass that conserve water while maintaining acceptable quality.

Significant variation in water use has been observed among Kentucky bluegrass cultivars in experiments conducted in growth chambers, greenhouses, and lysimeter-based field studies (5, 6, 14). Although growth chambers and greenhouses have the advantage of more controlled environments, they do not necessarily represent water use in the field where conditions are more variable. Lysimeters may restrict soil volumes for root growth and alter a number of environmental conditions and physiological properties of turfgrasses, all of which may impact water use (2).

Field studies investigating drought tolerance in Kentucky bluegrass have been conducted by completely withholding irrigation and measuring plant responses (7, 9, 12, 13). However, field studies are needed to evaluate the relative performance of Kentucky bluegrass cultivars under less than well-watered conditions, but where some irrigation is allowed. In this study we used wilt-based irrigation, which is a practical approach of waiting until drought stress is visible before irrigating the turfgrass.

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Type†	Cultivar
Aggressive	Limousine
	Touchdown
BVMG	Abbey
	Baron
	Envicta
Common	Kenblue
	Park
	Wellington
Compact	Diva
	Moonlight
	Skye
Compact America	Apollo
	Bedazzled
	Kingfisher
	Langara
	Unique
Compact Midnight	Award
	Blue Velvet
	Midnight
	Midnight II
	Nu Destiny
European‡	Bartitia
	Blue Knight
Hybrid Bluegrasses	Longhorn
	Thermal Blue Blaze
Julia	Julia
Mid-Atlantic	Cabernet
	Eagleton
	Preakness
Shamrock	Shamrock

† Kentucky bluegrass classification types as described in Bonos et al.(1).

‡ Blue Knight and Bartitia have since been reclassified as "Other Type" (4).

Table 1. Phenotypic types and cultivars of Kentucky bluegrasses and hybrid bluegrasses.

Kentucky bluegrasses have been classified into phenotypic groups (1, 10). Previous studies have indicated significant dehydration avoidance in cultivars among the different groups (7), suggesting phenotypic groupings of Kentucky bluegrass cultivars may be useful in predicting drought tolerance. Because cultivar turnover is rapid in the turfgrass industry, determining the relative irrigation requirements of phenotypic groups may enable researchers to predict irrigation requirements of cultivars not included in any particular study.

A large rainout shelter near Manhattan, KS offered a unique opportunity to compare seasonal irrigation amounts among multiple Kentucky bluegrass cultivars in the transition zone. By shielding plots from rainfall, water could be withheld until wilt symptoms were evident. Our objectives were to identify Kentucky bluegrass cultivars and phenotypic groups that maintain better visual quality with less irrigation, using wilt-based irrigation. We hypothesized that if visual quality was good at the beginning of the season, we could maintain minimally acceptable quality in Kentucky bluegrass (for example, for a moderately-maintained golf course rough with in-ground sprinklers) by irrigating when at least 50% of a given cultivar showed signs of wilt. Two hybrid bluegrasses were also included in the study.

Materials and Methods

This study was conducted at the Kansas State University Rocky Ford Turfgrass Research Center near Manhattan, KS. Data were collected from June 19 to October 1, 2007 (105 days), and June 22 to October 7, 2009 (108 days). Data were not collected in 2008 because of a bluegrass billbug (*Sphenophorus parvulus* Gyllenhal) infestation. The soil at the site was a Chase silt loam (fine, smectitic, mesic Aquertic Argiudoll).

Turfgrasses in the study included 28 Kentucky bluegrass cultivars and two hybrid bluegrasses (Table 1). Commercially available cultivars of Kentucky bluegrass were selected to

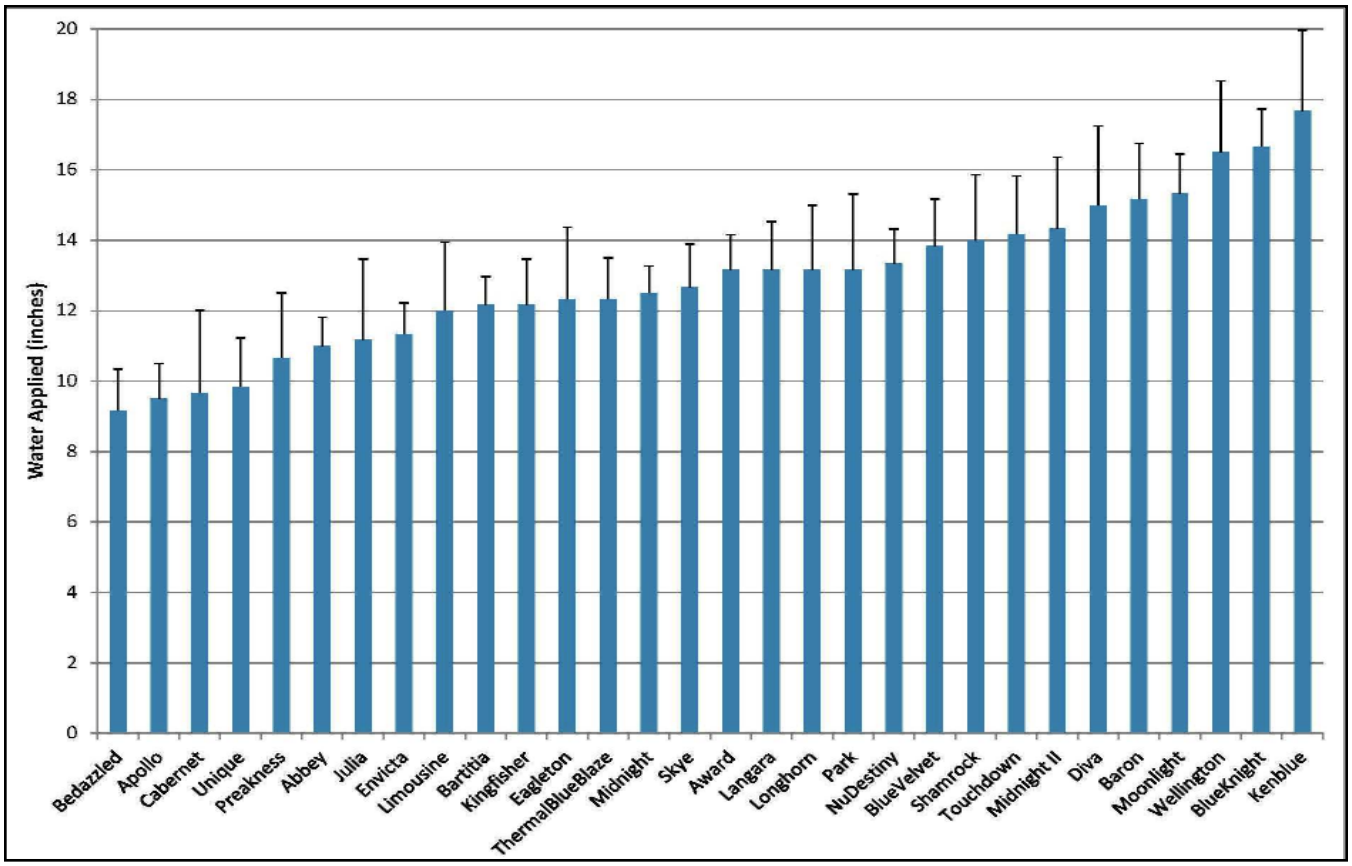

Figure 1. Water applied to Kentucky bluegrass cultivars and hybrid bluegrasses, averaged over the periods June 19 to October 1, 2007 (105 days) and June 22 to October 7, 2009 (108 days), at Manhattan, KS. Error bars denote standard error.

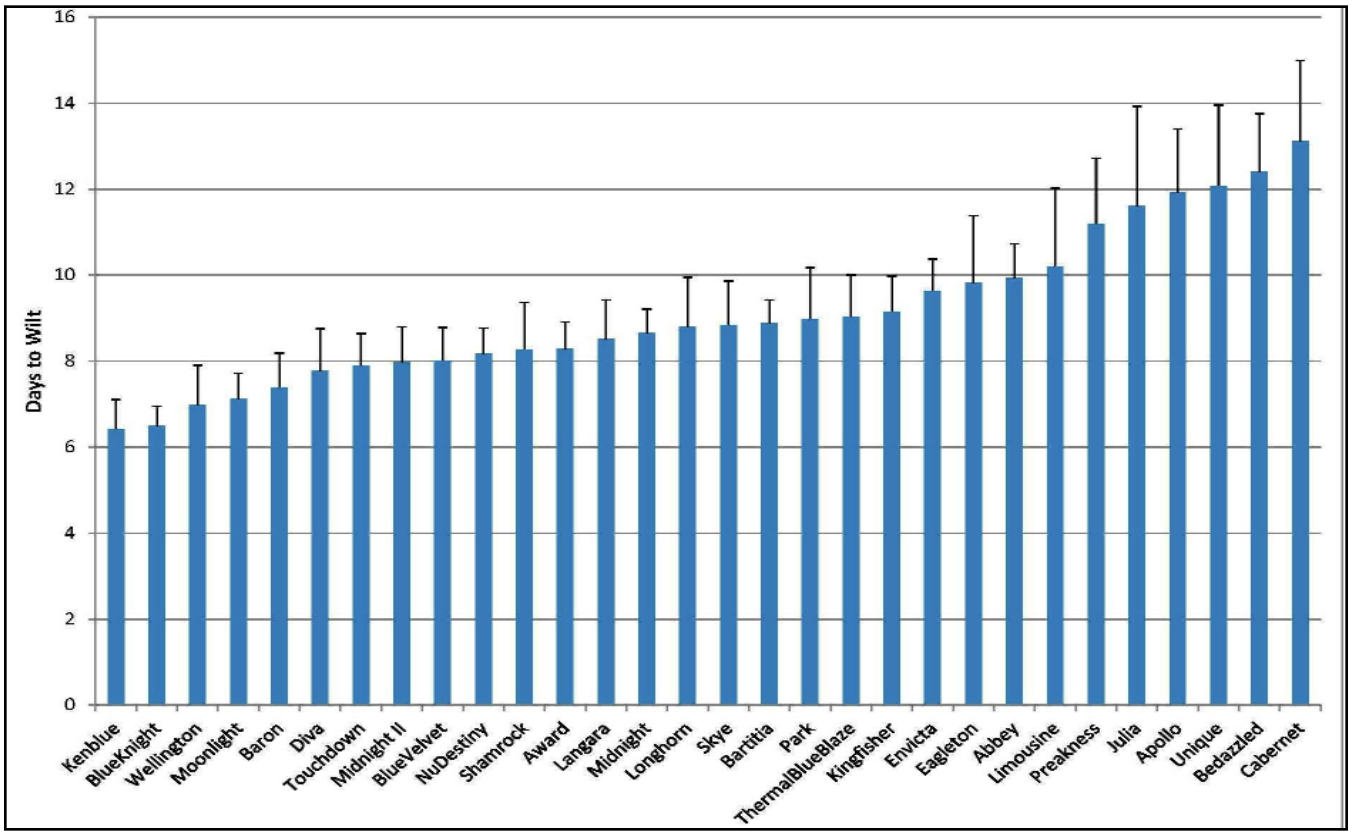

Figure 2. Days to wilt between irrigations among Kentucky bluegrass cultivars and hybrid bluegrasses, averaged over the periods June 19 to October 1, 2007 (105 days) and June 22 to October 7, 2009 (108 days), at Manhattan, KS.

include representatives from major Kentucky bluegrass phenotypic groups (1, 10). When comparing groups, only those with three or more cultivars in a group were used. Additionally, because visual quality was of interest in our research, cultivars were selected based on performance in the NTEP trials (11). Plots were arranged in a randomized complete block design with three replications. Ninety plots measuring 3.7 by 4.0 feet were bordered by metal edging (4-inch depth) to prevent lateral soil water movement.

The plots were well watered until the study began. Thereafter, water was withheld until 50% or more of a plot displayed drought symptoms. At that point, one inch of water was applied by hand through a fan spray nozzle attached to a hose and the amount recorded; a meter was attached to ensure proper application amount. Turfgrass quality and drought stress symptoms were evaluated daily. This process continued until the end of the study, after which all plots were re-watered and allowed to recover. Plots were mowed weekly with a rotary mower at a 3-inch mowing height.

Turfgrass quality evaluations, based on color, density, and uniformity of the canopies, were made using a visual rating scale of 1 to 9, with 1 = brown turf, 6 = minimally acceptable for a golf course rough or home lawn, and 9 = optimum turf (15). Drought stress was defined as the turf displaying wilting, failure of the canopy to remain upright after foot traffic, and a general darkening color of the turf. Because changes in drought stress were sometimes rapid from day to day, particularly under conditions of high temperatures, it was not unusual for irrigation to be applied when greater than 50% of a plot (for example, up to 70 or 80%) displayed drought stress.

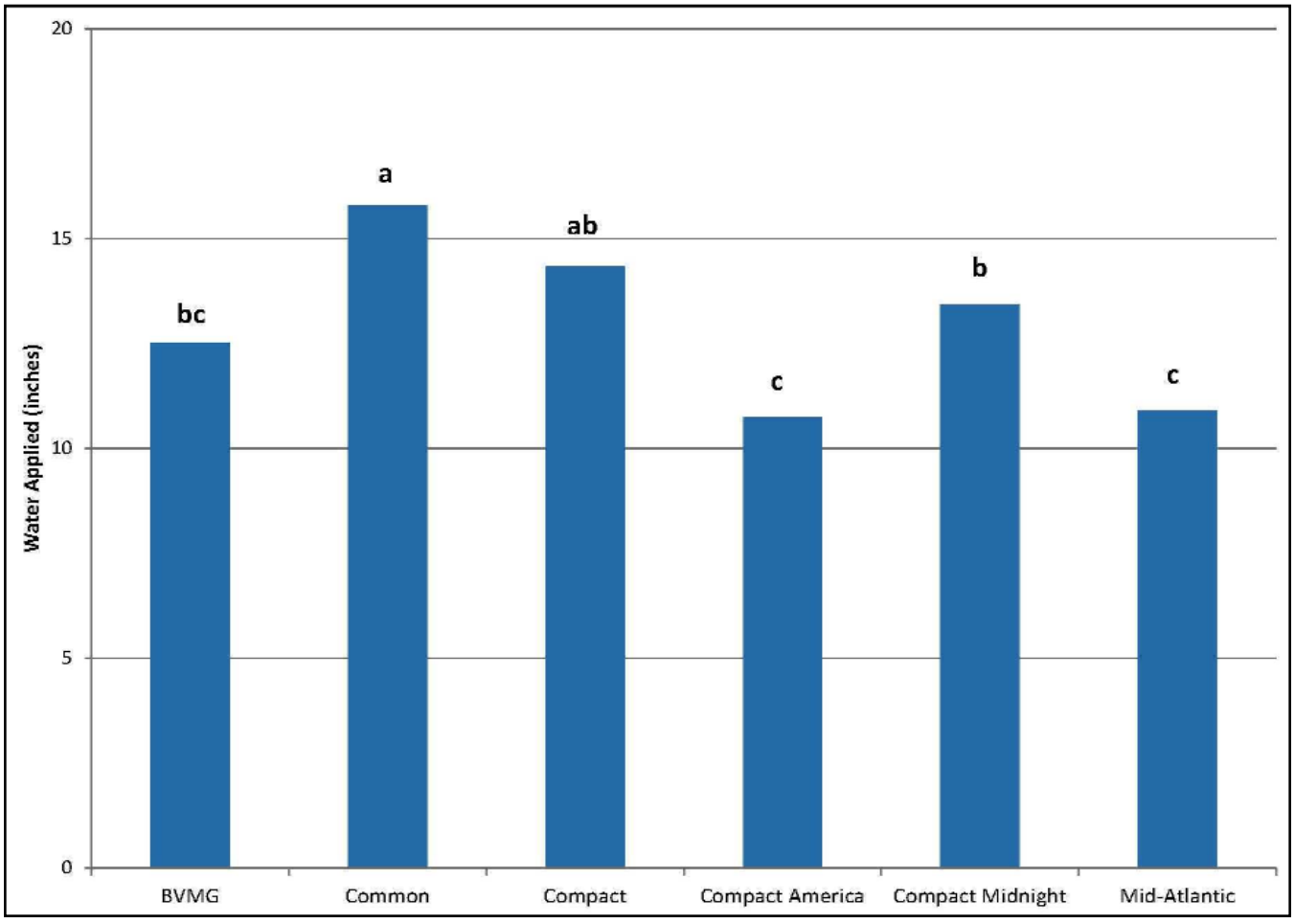

Figure 3. Water applied to Kentucky bluegrass phenotypic groups, averaged over the periods June 19 to October 1, 2007 (105 days) and 22 June22 to October 7, 2009 (108 days), at Manhattan, KS.

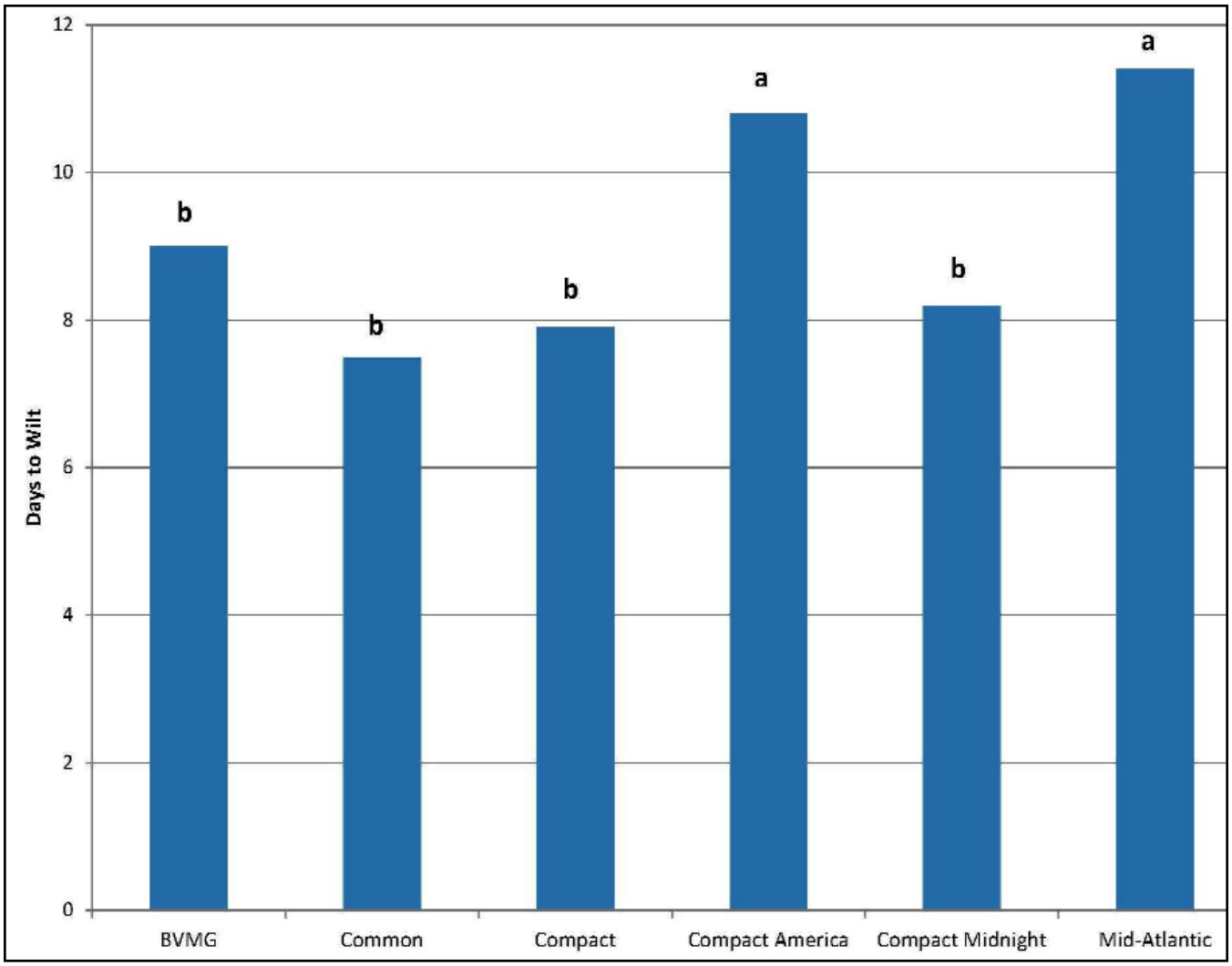

Figure 4. Days to wilt between irrigations among Kentucky bluegrass phenotypic groups, averaged over the periodsJune 19 to October 1, 2007 (105 days) and June 22 to October 7, 2009 (108 days), at Manhattan, KS.

Results

Total Water Applied and Days to Wilt between Irrigation Cycles

Water applications, averaged over the approximate 3.5-month period in each year of the study, ranged widely from 9.2 inches (0.6 inches/week) in 'Bedazzled' to 17.7 inches (1.2 inches/week) in 'Kenblue' (Figure 1). In 'Bedazzled', 'Apollo', 'Cabernet' and 'Unique', 9.8 inches (0.64 inches/week) or less of water was applied, which was significantly less than 'Kenblue', 'Blue Knight', 'Wellington', 'Moonlight', 'Baron', 'Diva', 'Midnight II', 'Touchdown', 'Shamrock', and 'Blue Velvet'. In the latter 10 cultivars, 13.8 inches (0.9 inches/week) or more of water was applied. However, there were no statistical differences among the 15 cultivars that received the least amount of water (Figure 1, 'Bedazzled' through 'Skye').

Days to wilt between irrigations, which was roughly inverse the amount of water applied (r= 0.91), ranged from 6.4 days in 'Kenblue' to 13.1 days in 'Cabernet', a difference of nearly one week (Figure 2). Days to wilt was greater in 'Cabernet', 'Bedazzled', 'Unique', and 'Apollo' (11.9 to 13.1 days) than in the 18 bluegrasses with the least days to wilt (6.4 to 9.0 days; 'Kenblue' through 'Park'). These intervals provide the practitioner with an estimate of irrigation frequency required to maintain the various Kentucky bluegrasses at a performance level similar to this study, at least in the transition zone of the U.S. In

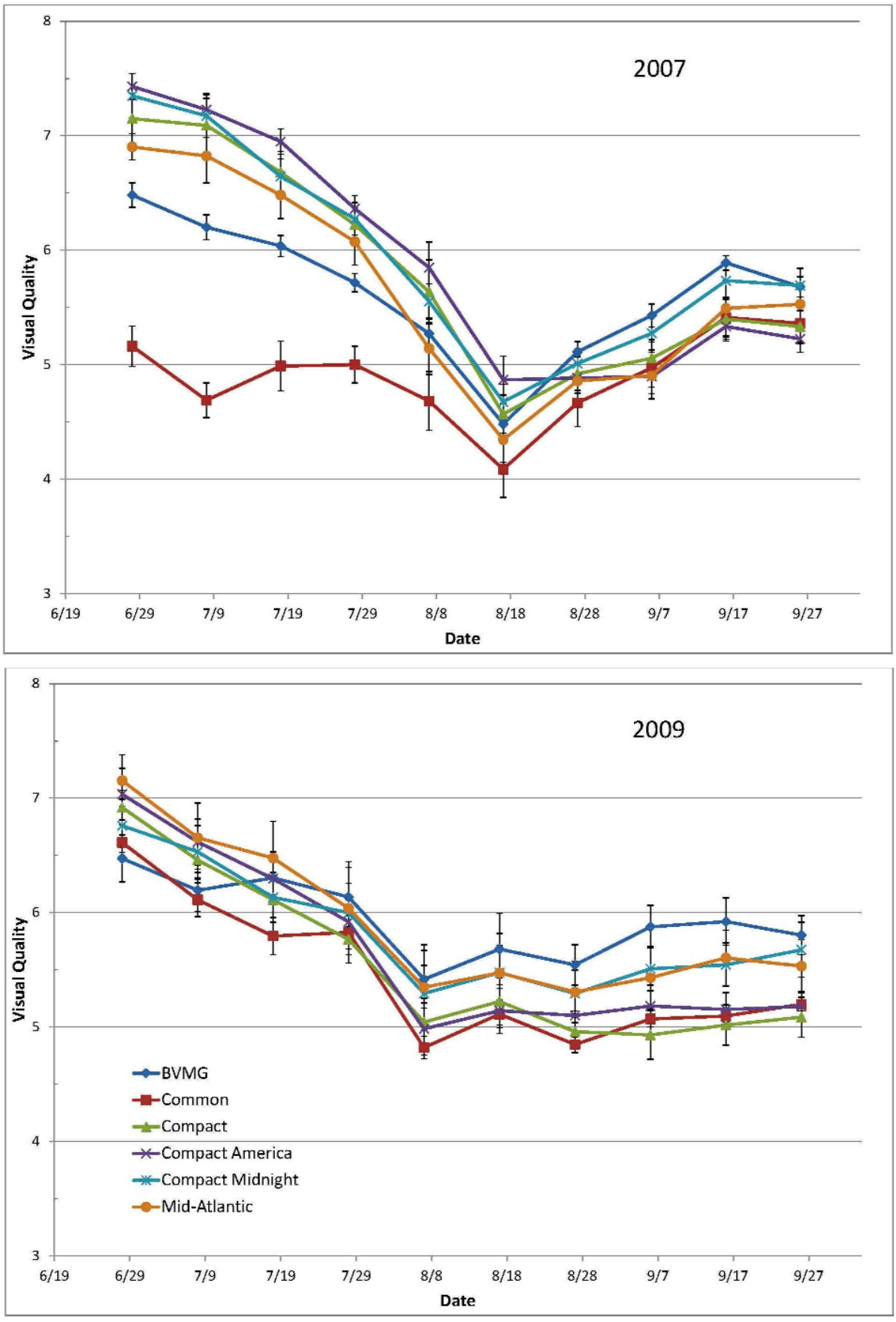

Figure 5. Visual quality of the six Kentucky bluegrass groups with three or more cultivars during 2007 (top) and 2009 (bottom). Data are presented in 10-day averages to illustrate seasonal trends. Error bars denote standard error.

Well-watered plots at beginning of dry-down study on June 4, 2007 (left) and plots at two months into the study on August 4, 2007 (right) where drought stress is evident in plots of Kentucky bluegrass.

addition to less frequent irrigation, cultivars with more days to wilt have a greater likelihood of receiving rainfall between irrigations; this could result in further water conservation and reduced irrigation costs.

Notably, all cultivars in the phenotypic group Mid-Atlantic ('Cabernet', 'Eagleton', and 'Preakness') and four of five in the Compact America group ('Apollo', 'Bedazzled', 'Kingfisher', and 'Unique') were among the 15 cultivars that received the least amount of water (Figure 1; Table 1). When averaged over all cultivars within each phenotypic group, 10.75 inches (0.71 inches/week) of water was applied to Compact America types and 10.9 inches (0.72 inches/week) to Mid-Atlantic types, which was less than the Common, Compact, and Compact Midnight groups (Figure 3).

Days to wilt was also greater in Mid-Atlantic and Compact America than in all other groups (Figure 4). Greater days to wilt may be related to a combination of a deep root system and lower evapotranspiration, or water use rates (4, 5). Mid-Atlantic types have lower water use because of their growth characteristics that promote high canopy resistance and low leaf area, both of which reduce evapotranspiration (6). Such canopy characteristics, which are also found in Compact America types, include decumbent growth habit, slow leaf growth rates, and high shoot and leaf densities.

Two of the three cultivars in the Common group ('Kenblue' and 'Wellington') ranked high in the amount of water applied, at 17.7 and 16.5 inches (1.2 and 1.1 inches/week), respectively (Figure 1). The last Common entry, 'Park', received 13.1 inches (0.86 inches/week) and was in the middle of the rankings. As a group, the Common types received more water (15.8 inches, 1.0 inches/week) than all other groups except Compact (Figure 3), which may have been related to higher evapotranspiration rates in Common types (5).

Visual Quality

With the exception of the Common types in 2007, the visual quality of all bluegrasses was good (i.e., >6) at the beginning of the study in each year (Figures 5). In all bluegrasses and in both years, however, visual quality declined to below six (Figures 5). This indicates waiting until 50% wilt to apply irrigation was insufficient to maintain acceptable visual quality in Kentucky bluegrass, at least for superintendents or homeowners who desire a moderate standard of quality in the stressful climate of the transition zone.

Perhaps visual quality could have been maintained at acceptable levels by applying water when only 25% of the plot exhibited symptoms of drought stress; further research is required. Our method may be appropriate, however, for superin-

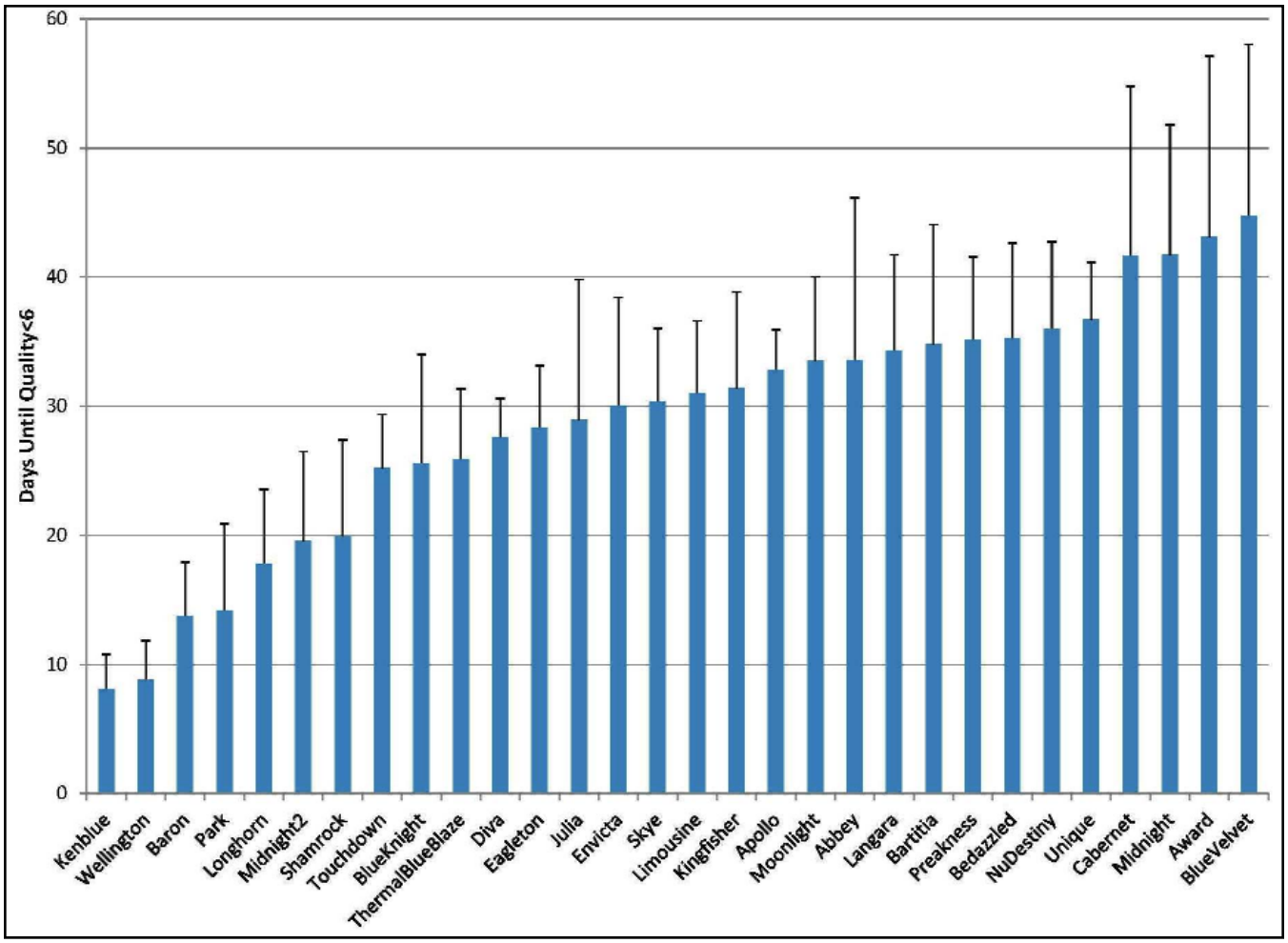

Figure 6. Days until visual quality of each cultivar declined to less than six among Kentucky bluegrass groups and hybrid bluegrasses, averaged over the periods 19 June to 1 Oct. 2007 (105 days) and 22 June to 7 Oct. 2009 (108 days).

tendents with low-maintenance roughs on their golf courses or the typical homeowner with no in-ground sprinklers, or where the primary concern is water conservation and some dormancy is acceptable. Visual quality in all bluegrasses remained above four, and recovery was rapid in the fall after resuming irrigation (data not shown).

Although visual quality declined to less than six in all cultivars, the time required to do so ranged widely from 8.1 days in 'Kenblue' to 44.8 days in 'Blue Velvet' (Figure 6). The decline was slower in 'Blue Velvet', 'Award', 'Midnight', 'Cabernet', 'Unique', and 'Nu Destiny' (36 to 44.8 days) than in 'Park', 'Baron', 'Wellington', and 'Kenblue' (8.1 to 14.2 days). Thus, four of five cultivars in the Compact Midnight group maintained quality longer than all cultivars in the Common group (Table 1). This is reflected in the group rankings, in which Compact Midnight types remained above a quality rating of six for longer than the Common as well as the BVMG types (Figure 7).

Relationships between Water Requirement and Visual Quality

The objective of the field study was to identify cultivars and phenotypic groups that retained acceptable visual quality with a minimum amount of water. Ideally, the cultivars or groups requiring the least amount of water would also have the highest visual quality. To better illustrate the relationships between irrigation applied and visual quality among the cultivars in our study, we created a scatter bi-plot (Figure 8). In this way, we identified general trends among cultivars that required the least amount of water but also had the highest visual quality. In Figure 8, cultivars with

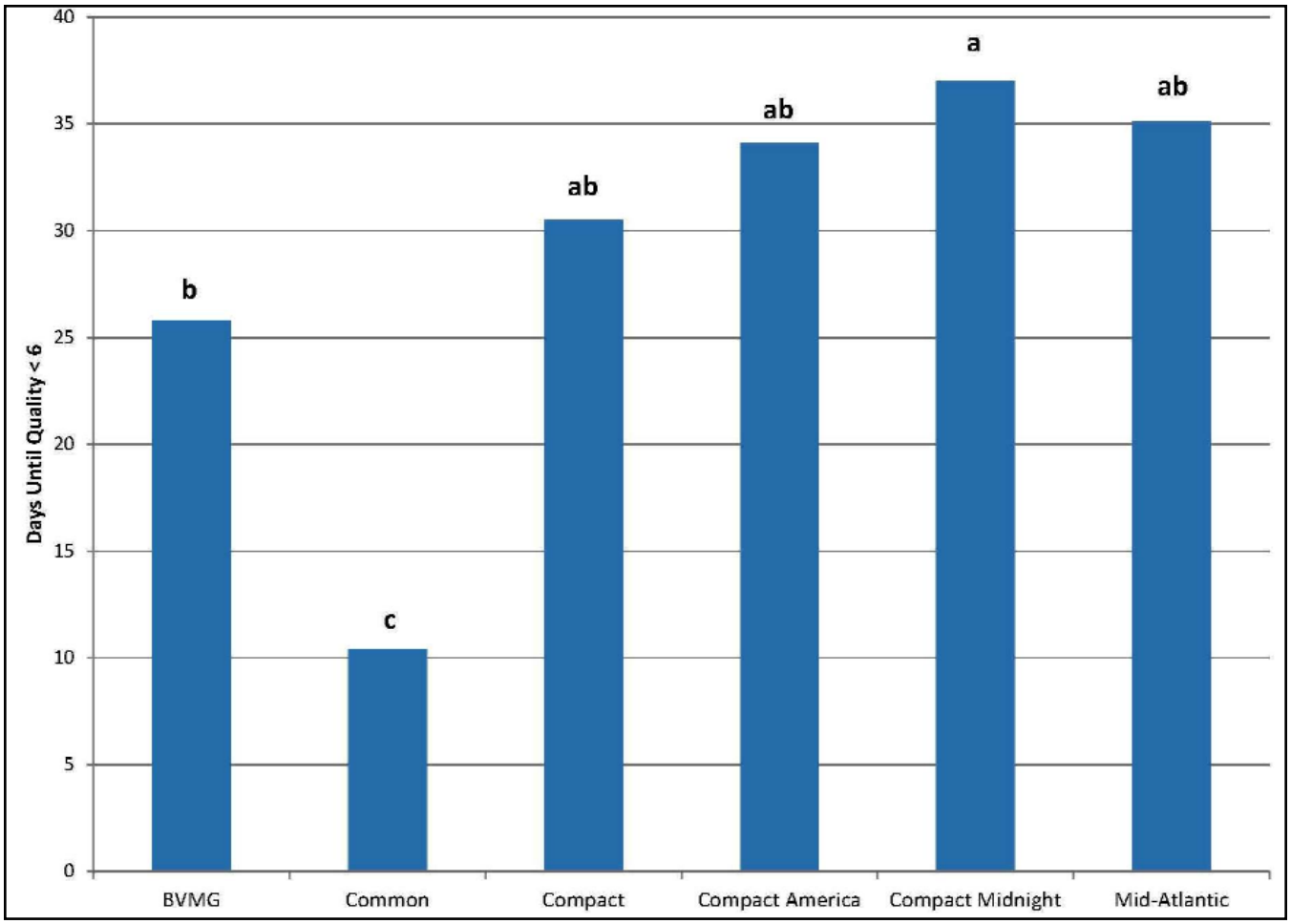

Figure 7. Days until visual quality declined to less than six, which was considered minimally acceptable, among Kentucky bluegrass phenotypic groups. Data were averaged over the periods 19 June to 1 Oct. 2007 (105 days) and 22 June to 7 Oct. 2009 (108 days).

the most favorable characteristics (i.e., low water applications and high visual quality) appear in the lower right section.

In general, irrigation applications were greater in bluegrasses with poorer quality ($r = 0.39$, $P<0.0001$) (Figure 8). A similar pattern was observed by other researchers in a growth chamber study, in which the authors concluded this pattern resulted from improved cultivars with morphological properties that both enhanced turf quality and reduced evapotranspiration (5). Such improved properties include compact or dwarfed growth habits, horizontal leaf orientation, and greater shoot density. Our study shows more direct evidence between water requirements and turf performance in the field.

All 15 bluegrasses with the lowest water applications (Figure 1, 'Bedazzled' through 'Skye') were also ranked among those with the highest visual quality (Figure 8); there were no statistical differences among cultivars with average visual quality greater than 5.5. The amount of water applied to these 15 cultivars with superior turf quality was also below the mean water applied to all 30 bluegrasses (Figure 3). Similarly, visual quality in 12 of the 15 bluegrasses that received the least water was greater than the mean of all 30 bluegrasses, although all 15 were statistically similar.

One hybrid bluegrass in our study, 'Thermal Blue Blaze', fell within the group of 15 receiving the least water but not the other ('Longhorn'). This supports results from other research, including at the same site as the current study, which indicates current hybrids have negligible advantage over Kentucky bluegrasses in tolerating drought stress (3, 12, 13, 16, 17, 18).

In contrast to the 15 top performers, six

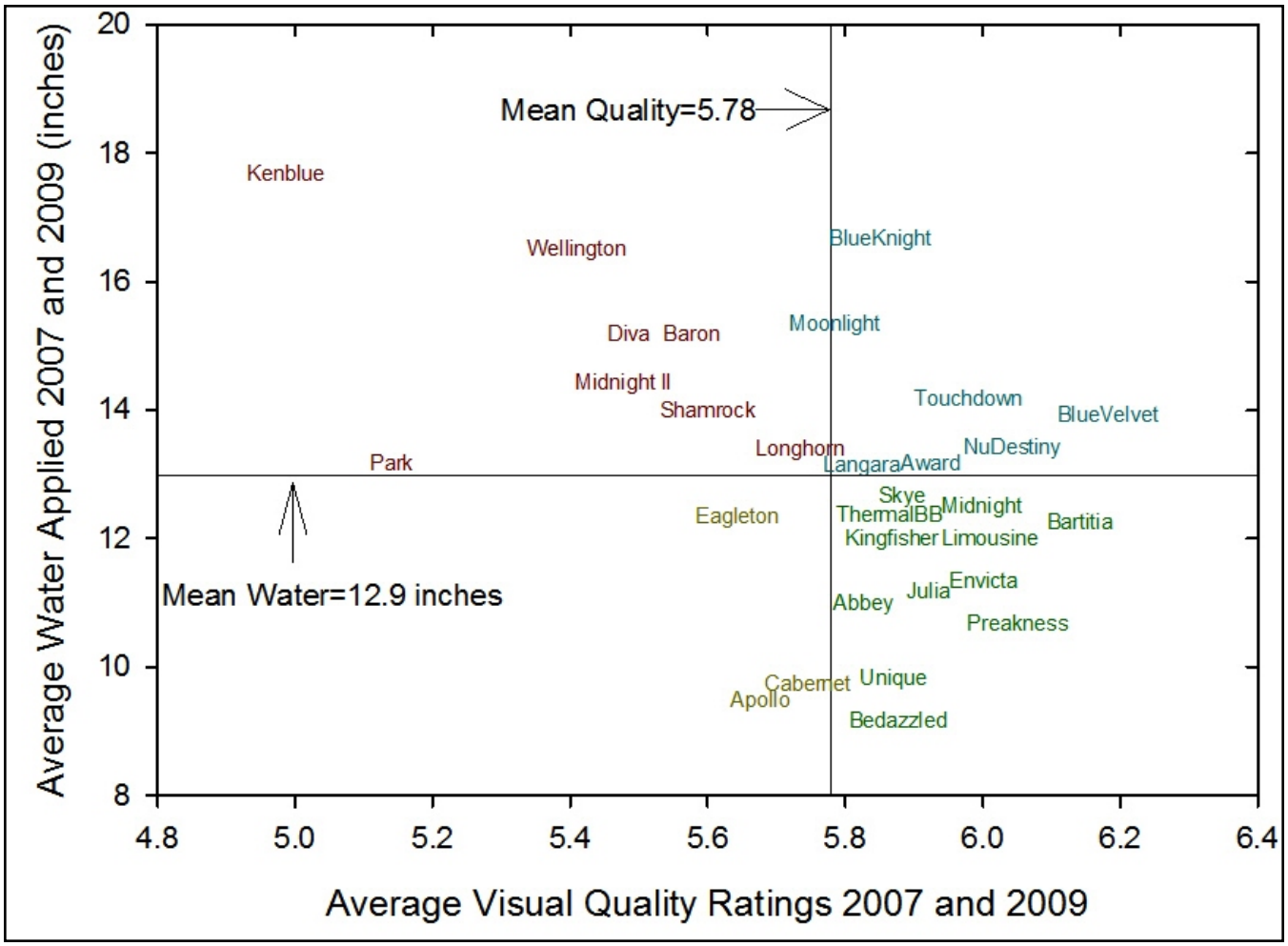

Figure 8. Water applied to Kentucky bluegrass cultivars and hybrid bluegrasses versus average visual quality ratings on a 1-9 scale with 9=optimum and 1=brown turf. Cultivars in different quadrants are denoted by different colors. Data were averaged over the periods 19 June to 1 Oct. 2007 (105 days) and 22 June to 7 Oct. 2009 (108 days).

cultivars were ranked within the group that received the most water and had the lowest visual quality (Figure 8). Those six cultivars, which included 'Kenblue', 'Wellington', 'Diva', 'Baron', 'Midnight II', and 'Shamrock', had neither the high visual quality nor low water requirement traits we were screening for in this study.

Conclusions

Results indicated that Kentucky bluegrass cultivar selection had significant impacts on water requirements and visual quality ratings. Among cultivars, differences in seasonal water applications were as great as 8.5 inches and differences in days to 50% wilt between irrigations were as great as 6.7 days. Based on statistical range tests, only 15 of the 30 cultivars were in the group that both received the least water and had the greatest visual quality. Results indicated that, under conditions similar to those in our study, Kentucky bluegrass in the Compact America and Mid-Atlantic phenotypic groups can be selected for their lower irrigation requirements without sacrificing visual quality, and types from those two groups may represent the best selections for breeding efforts to achieve such goals.

Acknowledgements

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Literature Cited

1. Bonos, S. A., W. A. Meyer, and J. A. Murphy. 2000. Classification of Kentucky bluegrass genotypes grown as spaced-plants. *HortScience* 35:910-913. (TGIF Record 67878)

2. Bremer, D. J. 2003. Evaluation of microlysimeters used in turfgrass evapotranspiration studies using the dual-probe heat-pulse technique. *Agron. J.* 95:1625-1632. (TGIF Record 107685)

3. Bremer, D. J., K. Su, S. J. Keeley, and J. D. Fry. 2006. Performance in the transition zone of two hybrid bluegrasses compared with Kentucky bluegrass and tall fescue.[Online]. Available at http://www.plantmanagementnetwork.org/ats/. (verified 25 June, 2010). *Applied Turfgrass Sci.* doi.10.1094/ATS-2006-0808-02-RS.(TGIF Record 113998)

4. Brooks-Gould, A. (ed.) 2004. Rutgers Turfgrass Proc. New Jersey Turfgrass Expo. 7-9 Dec. 2004. New Jersey Turfgrass Assoc. Atlantic City, New Jersey.

5. Ebdon, J. S., and A. M. Petrovic. 1997. Relationship between turfgrass quality performance and evapotranspiration rate in cultivars of Kentucky bluegrass. *J. Turfgrass Mngmt* 2(2):1-12. (TGIF Record 40224)

6. Ebdon, J. S., and A. M. Petrovic. 1998. Morphological and growth characteristics of low- and high-water use Kentucky bluegrass cultivars. *Crop Sci.* 38:143-152. (TGIF Record 41997)

7. Keeley, S. J., and A. J. Koski. 2001. Dehydration avoidance of diverse *Poa pratensis* cultivars and cultivar groups in a semi-arid climate. *Intl. Turf. Soc. Res. J.* 9:311-316. (TGIF Record 74341)

8. Lyman, G. T., C. S. Throssell, M. E. Johnson, G. A. Stacey, and C. D. Brown. 2007. Golf course profile describes turfgrass, landscape and environmental stewardship features. Online. *Applied Turfgrass Science* doi:10.1094/ATS-2007-1107-01-RS. (TGIF Record 130525)

9. Merewitz, E., W. Meyer, S. A. Bonos, and B. Huang. 2010. Drought stress responses and recovery of Texas x Kentucky hybrids and Kentucky bluegrass genotypes in temperate climate conditions. *Agron. J.* 102:258-268. (TGIF Record 159785)

10. Murphy, J. A., S. Bonos, and P. Perdomo. 1997. Classification of *Poa pratensis* genotypes. *Intl. Turf. Soc. Res. J.* 8:1176-1183. (TGIF Record 61135)

11. National Turfgrass Evaluation Program. 2001. 1995 National Kentucky bluegrass test. Rep. 1996-2000 Data Final report. NTEP, Beltsville, Maryland. (TGIF Records 77316 and 77317)

12. Richardson, M. D., D. E. Karcher, K. Hignight, and D. Rush. 2008. Drought tolerance and rooting capacity of Kentucky bluegrass cultivars. *Crop Sci.* 48:2429-2436. (TGIF Record 142705)

13. Richardson, M. D., D. E. Karcher, K. Hignight, and D. Rush. 2009. Drought tolerance of Kentucky bluegrass and hybrid bluegrass cultivars [Online]. *Applied Turfgrass Science* 10.1094/ATS-2009-0112-01-RS (TGIF Record 143680)

14. Shearman, R. C. 1986. Kentucky bluegrass cultivar evapotranspiration rates. *HortScience* 21:455-457. (TGIF Record 8691)

15. Skogley, C. R., and C. D. Sawyer. 1992. Field research. Pages 589-614. *In* D. V. Waddington, R. N. Carrow, and R. C. Shearman (eds.) Turfgrass. 32nd ed. ASA, CSA, SSSA, Madison, WI. (TGIF Record 26035)

16. Su, K., D. J. Bremer, S. J. Keeley, and J. D. Fry. 2007. Effects of high temperature and drought on a hybrid bluegrass compared with Kentucky bluegrass and tall fescue. *Crop Sci.*

47:2152-2161. (TGIF Record 128784)

17. Su, K., D. J. Bremer, S. J. Keeley, and J. D. Fry. 2008. Rooting characteristics and canopy responses to drought of turfgrasses including hybrid bluegrasses. *Agron. J.* 100:949-956. (TGIF Record 142432)

18. Su, K., D. J. Bremer, S. J. Keeley, and J. D. Fry. 2009. Mowing and drought effects on a hybrid bluegrass compared with a Kentucky bluegrass. *Int. Turf. Soc. Res. J.* 11:871-882. (TGIF Record 150968)