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# Drought Tolerance of Kentucky Bluegrass and Hybrid Bluegrass Cultivars

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## Abstract

The development of drought-tolerant turf cultivars can have a positive impact on future water resources. The objective of the following research was to evaluate the field drought tolerance of nine Kentucky bluegrass (*Poa pratensis* L.) cultivars and eighteen hybrid bluegrass (primarily *P. pratensis* × P. *arachnifera* Torr.) cultivars. The bluegrass entries were established in the field in Albany, OR, and evaluated under drought stress in the summer of 2006 and 2007. Drought tolerance and recovery following drought were measured using digital image analysis and were defined as the number of days until a cultivar reached 50% green tissue. Several Kentucky bluegrass cultivars, including Mallard, Bluestone, and Arrow, demonstrated significantly better drought tolerance than other Kentucky bluegrass and hybrid bluegrass cultivars. One hybrid bluegrass cultivar, Longhorn, and several experimental hybrids, had excellent drought tolerance in this trial. However, many of the hybrids tested in this trial did not have superior drought tolerance characteristics compared to the Kentucky bluegrasses tested. These results demonstrate that there is wide variability in drought tolerance among both Kentucky bluegrass and hybrid bluegrass and the broad screening of this genetic material under limited water can provide turfgrass managers with selections that can ultimately conserve water. In addition, these results demonstrate that there are no clear differences in drought tolerance between hybrid bluegrasses and Kentucky bluegrass.

## Introduction

The development of plants with improved tolerance to limited or low-quality water remains a critical research objective for the entire green industry, especially as landscape irrigation practices become more restrictive across the United States. Although many drought tolerance mechanisms are utilized by plants, the identification of turfgrass species and cultivars that can withstand long periods without water can prolong the need for supplemental irrigation and conserve water resources (6). This is especially beneficial in areas where rainfall is sporadic during the summer season, as the ability of the plant to maintain a favorable water balance until the next rainfall event could greatly minimize the need for supplemental irrigation while producing an acceptable quality turf. The maintenance of green tissue is an important consideration in turfgrass systems, as a hydrated lawn provides many desirable benefits over a dormant lawn including cooling, fire prevention, and safety for use (2).

Kentucky bluegrass is a widely-planted cool-season turfgrass in both high- and low-maintenance turf systems. This species has also been widely hybridized with other *Poa* species in an attempt to improve adaptability and performance. The mostly widely-used hybridizations have involved crosses between Kentucky bluegrass and Texas bluegrass (*Poa arachnifera* Torr.) (9,14). However, other *Poa* species have also served as crossing materials in recent hybridizations, including narrow-leaved meadow grass (*Poa angustifolia* L.), *P. densa* Troitsky, and wood bluegrass (*P. nemoralis* L.) (C. Rose-Fricker, *unpublished*). Alternative *Poa* spp. have traits that could be desirable in the future development of turf-type bluegrasses (5), but they have not been widely tested to date.

Numerous studies have documented differences in either drought tolerance (1,3,11,12,13), summer stress tolerance (7,8), or water use efficiency (4) of Kentucky bluegrass varieties and experimental hybrids. However, many of these studies have been conducted under greenhouse and growth chamber conditions and may not accurately reflect responses to drought stress under field conditions. In addition, these studies have tested a limited number of cultivars.

Techniques have been recently developed to assess the drought tolerance of turfgrasses under prolonged water deficit stress (6,11). The specific objective of those research projects was to quantitatively identify turfgrass cultivars that can maintain green cover for longer periods without water. Those studies were limited to several breeding populations of tall fescue (*Festuca arundinacea* Schreb) (6) and a small sample of Kentucky bluegrass cultivars (11). As water restrictions in landscapes become more prevalent, a broader range of both cool- and warm-season grasses needs to be screened in this fashion to identify superior cultivars for use in water-limited environments. The objective of this research was to assess the drought tolerance of a more broad range of Kentucky bluegrass (KBG) and hybrid bluegrass (HBG) cultivars.

## Experimental Area for Drought Study

All studies were conducted at the NexGen Turf Research LLC research facilities in Albany, OR (44°33'N, 123°04'W), during the 2006 and 2007 growing seasons. On 4 September 2005, eighteen hybrid bluegrass (HBG) and nine Kentucky bluegrass (KBG) cultivars (Table 1) were seeded at 3.0 lb/1000 $ft^2$ into 3.3 × 6.6-ft plots on a native silt-loam soil (Woodburn silt loam, fine-silty, mixed, superactive, mesic Aquultic Argixerolls, pH 5.6 to 6.5, organic matter 3 to 5%). This soil is generally classified as a deep (>6.6 ft) topsoil with no zones in the upper 2.0 m that would restrict root development.

Of the eighteen hybrid bluegrass entries in the trial, 13 of those entries were hybrids between *P. pratensis* × *P. arachnifera* (Table 1). Additional, unique hybrids were also tested, including crosses between *P. pratensis* and *P. angustifolia* L. (3 entries), *P. densa* Troitsky (1 entry), and *P. nemoralis* L. (1 entry). Each entry was replicated three times in a randomized complete block experimental design. Irrigation was provided as needed during establishment to promote germination and establishment and at a rate of 1.0 inch per week in the absence of rainfall to provide optimal growing conditions. Following establishment, the experimental area was mowed 2 to 3 times per week at a height of 1.0 inch with clippings returned. The authors recognize that this shorter mowing height is likely not the optimum height to maximize drought tolerance. However, a previous experiment conducted in a similar fashion indicated minimal differences in Kentucky bluegrass cultivar response at two distinct mowing heights (1.0 and 1.5 inches) (K. Hignight, *unpublished*). Fertilizer was applied in March, April, May, and October of each season with a 19-3-16 ($N:P_2O_5:K_2O$) product (Woodburn Royal Green, Woodburn Fertilizer Inc., Woodburn, OR) at a rate of 169.0 lb/acre. Prior to initiating drought stress in both seasons, plots were evaluated for turfgrass quality on a 1 to 9 scale with 9 being optimum quality and 5 being minimally acceptable quality.

Table 1. Statistical parameters for predicting dry-down characteristics of Kentucky bluegrass cultivars. Smaller (more negative) slope values translate to more rapid changes in green cover over time. Days50 is the predicted number of days (from irrigation withheld) until the turf reaches 50% green cover. An average Days50 was computed (*data not shown*) and cultivars are sorted by that average from most drought tolerant to least drought tolerant.

| | | | 2006 | | | | | 2007 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Days50** | **(SE)** | **Slope** | **(SE)** | $R^2$ | **Days50** | **(SE)** | **Slope** | **(SE)** | $R^2$ |
| **Rank** | **Selection** | **Species** | **Drought tolerance** | | | | | | | | | |
| 1 | 103-509 | *P. pratensis* × *P. angustifolia* | 33.1 | (0.43) | -0.105 | (0.0112) | 0.95 | 32.2 | (1.12) | -0.055 | (0.0082) | *0.76* |
| 2 | Mallard | *P. pratensis* | 31.9 | (0.19) | -0.122 | (0.0063) | 0.99 | 32.9 | (0.82) | -0.072 | (0.0098) | *0.83* |
| 3 | Longhorn | *P. pratensis* × *P. arachnifera* | 32.7 | (0.41) | -0.103 | (0.0103) | 0.96 | 31.0 | (2.01) | -0.034 | (0.0067) | *0.57* |
| 4 | Bluestone | *P. pratensis* | 30.6 | (0.48) | -0.102 | (0.0115) | 0.95 | 32.6 | (1.12) | -0.048 | (0.0065) | *0.77* |
| 5 | Arrow | *P. pratensis* | 31.7 | (0.20) | -0.119 | (0.0067) | 0.99 | 30.9 | (1.10) | -0.051 | (0.0068) | *0.78* |
| 6 | AKB449 | *P. pratensis* | 30.6 | (0.34) | -0.107 | (0.0088) | 0.98 | 31.4 | (0.76) | -0.079 | (0.0104) | *0.85* |
| 7 | A00TB-99 | *P. pratensis* × *P. arachnifera* | 29.6 | (0.19) | -0.127 | (0.0069) | 0.99 | 31.7 | (1.06) | -0.067 | (0.0109) | *0.76* |
| 8 | 1QG-38 | *P. pratensis* | 31.3 | (0.26) | -0.114 | (0.0078) | 0.98 | 29.9 | (1.05) | -0.065 | (0.0100) | *0.80* |
| 9 | AKB287 | *P. pratensis* | 28.9 | (0.48) | -0.092 | (0.0088) | 0.96 | 29.5 | (0.94) | -0.061 | (0.0080) | *0.84* |
| 10 | A00TB-101 | *P. pratensis* × *P. arachnifera* | 29.3 | (0.62) | -0.109 | (0.0162) | 0.93 | 28.3 | (1.16) | -0.063 | (0.0101) | *0.78* |
| 11 | 1A4-529 | *P. pratensis* × *P. densa* | 28.4 | (0.91) | -0.083 | (0.0135) | 0.89 | 28.2 | (1.07) | -0.063 | (0.0094) | *0.81* |
| 12 | 1A3-1015 | *P. pratensis* | 29.8 | (0.39) | -0.113 | (0.0112) | 0.97 | 26.4 | (1.58) | -0.052 | (0.0098) | *0.68* |
| 12 | AKB958 | *P. pratensis* | 28.8 | (0.31) | -0.101 | (0.0069) | 0.98 | 27.3 | (1.08) | -0.060 | (0.0087) | *0.81* |
| 13 | A03TB-256 | *P. pratensis* × *P. arachnifera* | 29.6 | (0.43) | -0.099 | (0.0094) | 0.97 | 25.9 | (1.53) | -0.042 | (0.0070) | *0.70* |
| 13 | Royce | *P. pratensis* | 29.7 | (0.65) | -0.114 | (0.0190) | 0.92 | 25.4 | (1.98) | -0.048 | (0.0108) | *0.59* |
| 14 | A03-TB-676 | *P. pratensis* × *P. arachnifera* | 27.6 | (0.56) | -0.101 | (0.0116) | 0.95 | 26.6 | (1.18) | -0.053 | (0.0077) | *0.79* |
| 14 | Cadet | *P. pratensis* | 27.8 | (0.53) | -0.102 | (0.0115) | 0.96 | 26.2 | (1.27) | -0.050 | (0.0075) | *0.76* |
| 15 | Broadway | *P. pratensis* | 26.7 | (0.45) | -0.124 | (0.0136) | 0.97 | 26.9 | (1.13) | -0.056 | (0.0082) | *0.79* |
| 15 | Julius | *P. pratensis* | 29.0 | (0.94) | -0.094 | (0.0181) | 0.87 | 24.2 | (1.21) | -0.044 | (0.0059) | *0.78* |
| 16 | A04TB-192 | *P. pratensis* × *P. arachnifera* | 26.7 | (0.26) | -0.114 | (0.0067) | 0.99 | 26.1 | (0.91) | -0.063 | (0.0080) | *0.86* |
| 16 | Thermal Blue | *P. pratensis* × *P. arachnifera* | 30.2 | (0.33) | -0.112 | (0.0093) | 0.98 | 21.8 | (1.06) | -0.058 | (0.0080) | *0.83* |
| 17 | A03TB-708 | *P. pratensis* × *P. arachnifera* | 24.8 | (1.82) | -0.063 | (0.0150) | 0.70 | 26.6 | (1.05) | -0.061 | (0.0086) | *0.82* |
| 18 | Midnight | *P. pratensis* | 27.2 | (0.81) | -0.093 | (0.0140) | 0.92 | 23.9 | (1.34) | -0.053 | (0.0086) | *0.76* |
| 19 | 1A4-312 | *P. pratensis* × *P. angustifolia* | 26.3 | (0.81) | -0.104 | (0.0169) | 0.92 | 24.7 | (1.04) | -0.057 | (0.0075) | *0.83* |
| 20 | 103-630 | *P. pratensis* × *P. angustifolia* | 23.0 | (1.87) | -0.061 | (0.0137) | 0.72 | 27.9 | (0.83) | -0.068 | (0.0084) | *0.87* |
| 21 | A03TB-390 | *P. pratensis* × *P. arachnifera* | 26.3 | (0.42) | -0.128 | (0.0132) | 0.97 | 23.9 | (1.22) | -0.052 | (0.0075) | *0.79* |
| 22 | A03TB-417 | *P. pratensis* × *P. arachnifera* | 26.9 | (0.67) | -0.110 | (0.0159) | 0.94 | 23.0 | (1.93) | -0.041 | (0.0084) | *0.60* |
| 23 | 1A4-221 | *P. pratensis* × *P. nemoralis* | 26.8 | (0.32) | -0.131 | (0.0108) | 0.98 | 22.3 | (0.99) | -0.053 | (0.0065) | *0.85* |
| 24 | Pp H8510 | *P. pratensis* | 27.1 | (0.28) | -0.127 | (0.0090) | 0.99 | 21.3 | (1.16) | -0.054 | (0.0078) | *0.81* |
| 25 | Fire & Ice | *P. pratensis* × *P. arachnifera* | 25.9 | (0.47) | -0.116 | (0.0118) | 0.97 | 21.0 | (1.62) | -0.048 | (0.0088) | *0.69* |
| 26 | A03TB-795 | *P. pratensis* × *P. arachnifera* | 27.6 | (0.55) | -0.112 | (0.0140) | 0.95 | 19.1 | (1.46) | -0.047 | (0.0076) | *0.73* |
| 27 | Solar Green | *P. pratensis* × *P. arachnifera* | 25.7 | (0.51) | -0.098 | (0.0092) | 0.97 | 18.4 | (1.88) | -0.044 | (0.0090) | *0.62* |

## Drought Stress and Recovery Evaluations

On 18 June 2006 and 21 June 2007, the experimental area was saturated with 2.0 inch of irrigation per day for three consecutive days to eliminate any dry areas and produce uniformly wet conditions across all plots. Immediately thereafter, irrigation was withheld to encourage drought stress symptoms. The response of entries to drought stress was evaluated weekly using digital image analysis techniques (10) to quantify the percent green turf cover for each plot as drought became more severe. In both years, plots were evaluated until all plots had fallen below 25% green turf cover and then the experimental area was saturated with 2.0 inch of irrigation to initiate drought recovery (initiated on 28 July 2006 and 10 August 2007). Thereafter, the experimental area was irrigated weekly with 1.0 inch water until plots reached 100% green cover.

## Statistical Analysis of Drought Study

Scatter plots of the percent green turf cover data versus days after irrigation withheld during drought stress and recovery indicated a strong nonlinear relationship. Furthermore, the data fit very well to a sigmoid variable slope model:

$$\text{green turf cover (\%)} = 100 \,/\, [\, 1+10^{(\text{Days50} - \text{DAI}) \times \text{Slope}} \,]$$

where DAI = days after irrigation was withheld and Days50 and Slope are estimated model parameters. Days50 is estimated to be the DAI when green turf cover = 50%. The Slope parameter defines how rapidly turf cover changes over time with more negative values representing steeper slopes of the sigmoid curve. A more detailed description of data collection methods and statistical analysis of the results have been described previously (6,11).

## Cultivar Response to Drought Stress

Temperatures during the two years of the study were in a desirable range for evaluating cultivar responses to drought stress, with average high temperatures ranging from 77 to 86°F during the predominance of the trial (Fig. 1). There were only a few days in both years of the trial in which daily maximum temperature exceeded 86°F, so heat stress was not likely a confounding factor in the trial. In addition, only one occurrence of rainfall (0.27 inch followed by 0.08 inch) was observed during the dry-down phase in 2007 and had a minimal effect on drought severity during the trial (Fig. 1). A significant rainfall occurred near the end of the dry-down in 2007 (Fig. 1) and corresponded to the timing of re-watering.

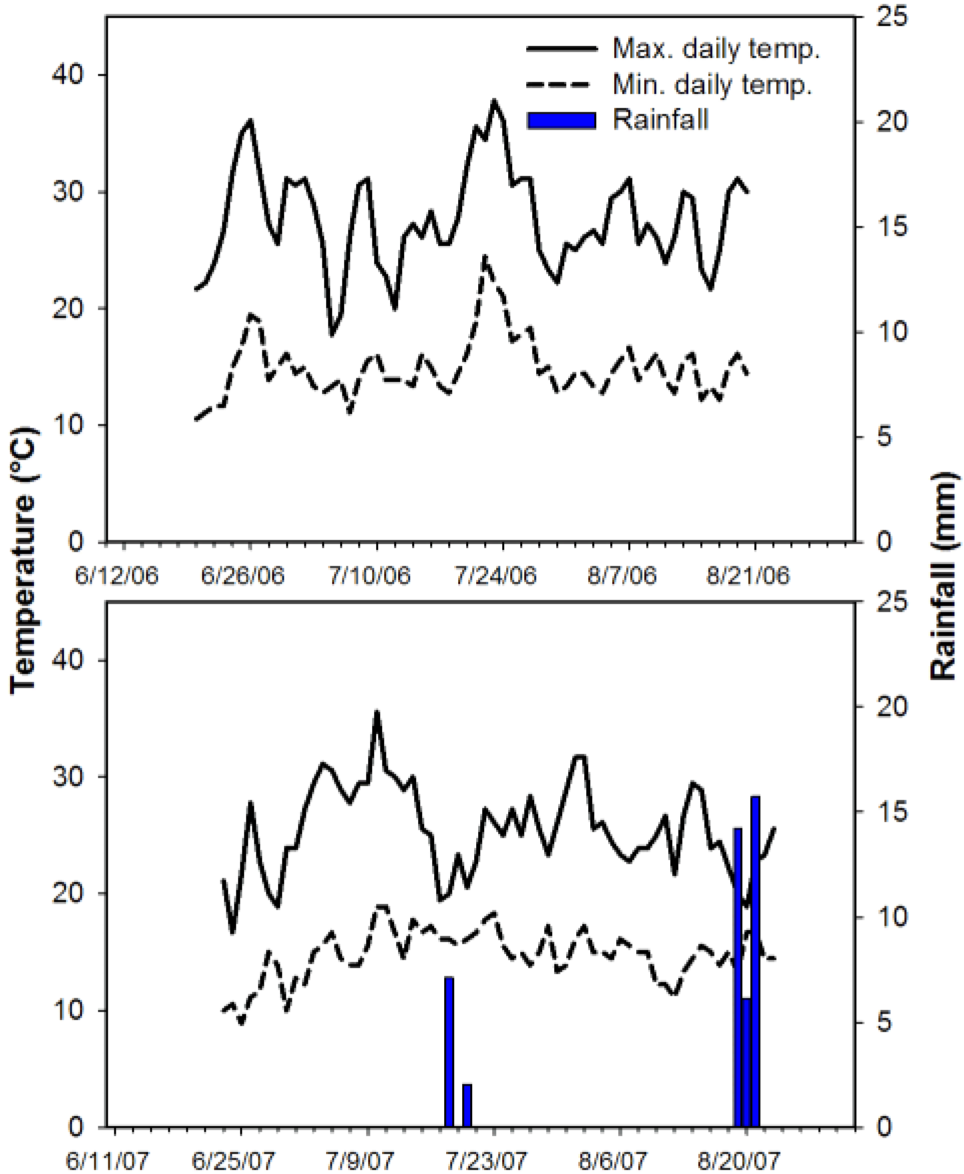


Fig. 1. Maximum and minimum temperatures and daily rainfall totals in Albany, OR, during the experimental periods.

As observed in previous studies (6,11), the sigmoid models used to predict turf coverage provided a good fit of the green turf cover data (*data not shown*), resulting in average $R^2$ values of 0.94 and 0.77 during drought stress in 2006 and 2007, respectively (Table 1). In both years of the trial, entries began to show initial symptoms of drought stress, as measured by loss of green cover, at 5 to 12 days after withholding irrigation (*data not shown*). The average number of days for entries to reach 50% green cover was 28.5 in 2006 and 26.5 in 2007 (Table 1). The commercially-available KBG cultivars, Mallard, Bluestone, and Arrow, demonstrated the best drought tolerance in both years of the trial, with Mallard reaching 50% green cover at 31.9 and 32.9 days in 2006 and 2007, respectively (Table 1, Figs. 2 and 3). Mallard was also the top-performing bluegrass in an earlier trial conducted under similar conditions (11). The present trial demonstrates that Kentucky bluegrass cultivars and experimental lines can also have excellent drought tolerance characteristics and improvements in this trait might also be made from crosses within *P. pratensis* as well as hybridization with related species.

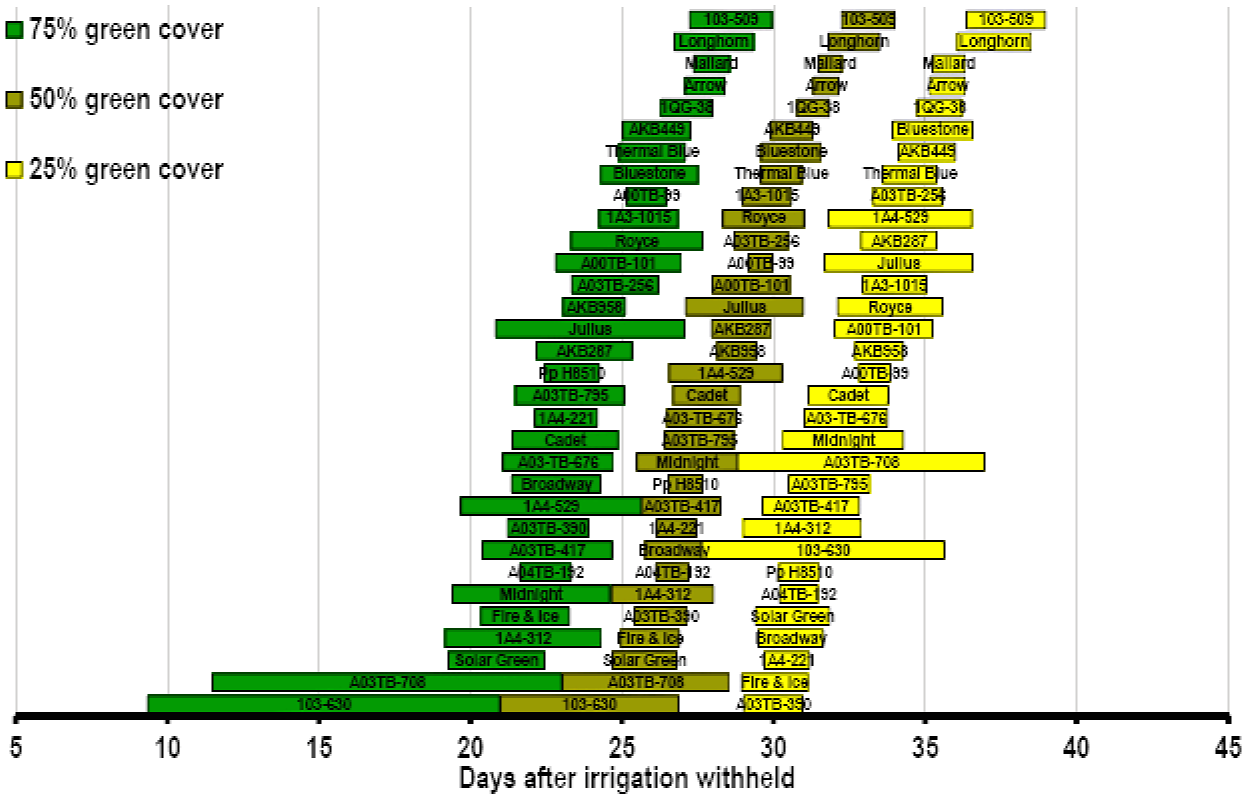


Fig. 2. Ninety-five percent confidence intervals for the number of days after water was withheld until bluegrass cultivars reached 75%, 50%, and 25% green cover in 2006. Within each green cover percentage, cultivars with overlapping bars were not significantly different.

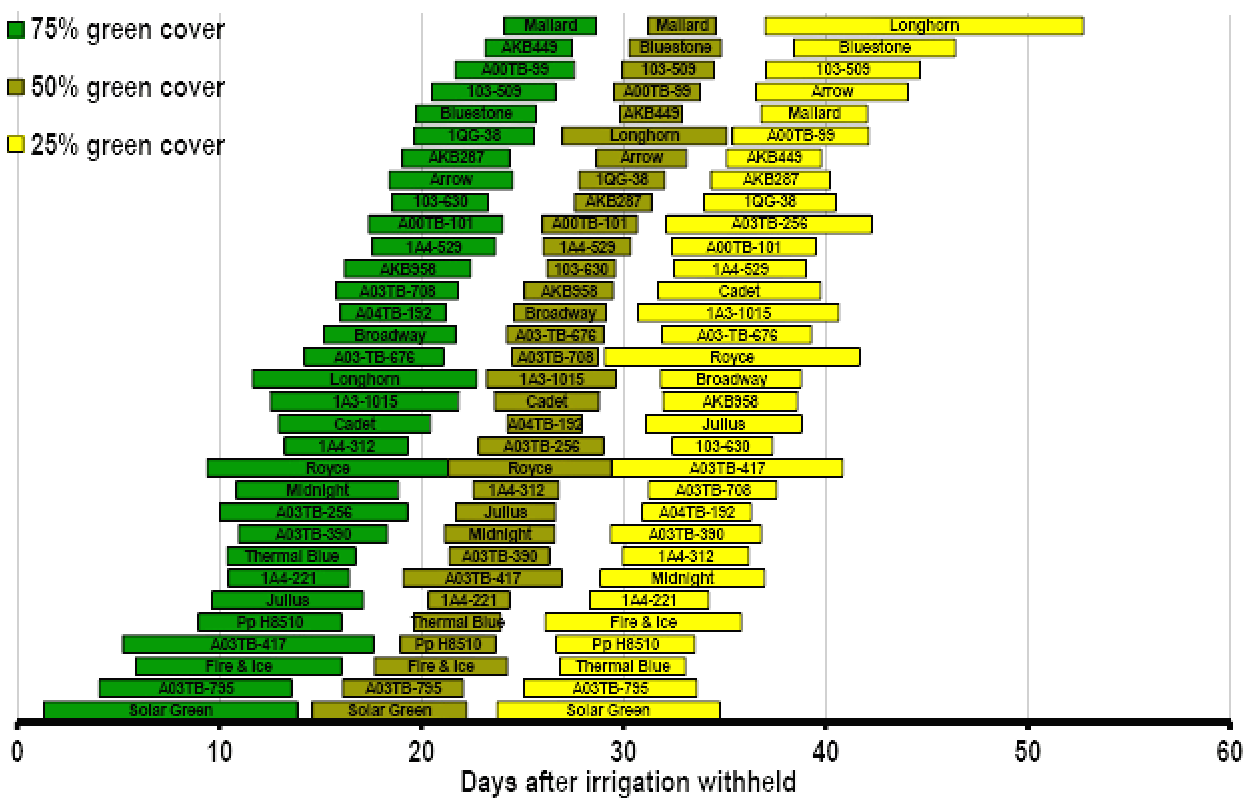


Fig. 3. Ninety-five percent confidence intervals for the number of days after water was withheld until bluegrass cultivars reached 75%, 50%, and 25% green cover in 2007. Within each green cover percentage, cultivars with overlapping bars were not significantly different.

Several HBG entries also exhibited excellent drought tolerance characteristics in this trial, including the cultivar, Longhorn, and the experimental entries, 103-509 and A00TB-99 (Table 1, Figs. 2 and 3). Interestingly, the most drought-tolerant entry in the trial was 103-509, an experimental hybrid between *P. pratensis* × *P. angustifolia*. Although most hybridization attempts with *Poa* spp. have focused on hybrids involving *P. arachnifera*, these results suggest other species may also be promising candidates for introducing desirable traits into Kentucky bluegrass. One experimental *P. pratensis* × *P. densa* hybrid, 1A4-529, also performed well under drought stress (Table 1, Figs. 2 and 3).

In general, most of the *P. pratensis* × *P. arachnifera* hybrids did not perform as well under these conditions as might be expected, based on much of the marketing literature surrounding these hybrids. Several HBG cultivars, such as Solar Green, Fire and Ice, and Thermal Blue, were among the most susceptible to drought stress and lost 50% of their green cover as much as 7 days earlier than the most drought-tolerant lines in 2006 and as much as 14 days earlier in 2007 (Table 1, Figs. 2 and 3). With the exception of the HBG entries mentioned previously (i.e., Longhorn and 103-509), most of the HBG entries tested in this trial were in the bottom half of the trial in relation to drought tolerance. However, it should be noted that these cultivars did not experience any significant heat stress during these experimental periods (Fig. 1), which could significantly affect their response to drought.

To date, the present study tested the largest sample of HBG cultivars and experimental hybrids in relation to drought tolerance and there was a wide range of drought tolerance among HBG in this trial (Table 1, Figs. 2 and 3). It should be noted that there are two other hybrid cultivars (Banderra and Thermal Blueblaze) that were not tested in this trial that are currently being grown in commercial seed production. Abraham et al. (1) reported nominal improvements in drought resistance in hybrid bluegrasses, with the most significant gains occurring when the KBG parent also had excellent drought resistance characteristics. Su et al. (12) and Bremer et al. (3) reported minimal differences in drought tolerance between HBG (cvs. Thermal Blue and Dura Blue) and KBG (cv. Apollo) cultivars. These data further corroborate previous studies (3,11), suggesting that hybrid bluegrasses will more likely have improved drought tolerance characteristics if the parents used to create those crosses also have good drought characteristics.

**Cultivar recovery following drought**. In general, those entries that had the best drought tolerance during dry-down were also the quickest to recover following drought (Table 2), similar to earlier reports on tall fescue (6). The recovery of entries to 50% green cover ranged from 4.4 to 10.9 days in 2006 and from 4.2 to 31.1 days in 2007 (Table 2). Selecting cultivars that recover quickly from drought stress is an important consideration, as the functional aspects of the turf are more quickly restored once rain or irrigation is available.

Table 2. Statistical parameters for predicting green-up of bluegrass cultivars after water was applied. Larger slope values translate to more rapid changes in green cover over time. Days50 is the predicted number of days (from irrigation applied) until the turf reaches 50% green cover. An average Days50 was computed (*data not shown*) and cultivars are sorted by that average from fastest recovery from drought to slowest recovery from drought.

| | | | 2006 | | | | | 2007 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Days50** | **(SE)** | **Slope** | **(SE)** | **$R^2$** | **Days50** | **(SE)** | **Slope** | **(SE)** | **$R^2$** |
| **Rank** | **Selection** | **Species** | **Drought recovery** | | | | | | | | | |
| 1. | Longhorn | *P. pratensis* × *P. arachnifera* | 4.4 | (0.43) | 0.159 | (0.0280) | 0.85 | 5.9 | (1.70) | 0.053 | (0.0129) | 0.66 |
| 2. | Bluestone | *P. pratensis* | 6.9 | (0.35) | 0.156 | (0.0209) | 0.91 | 4.2 | (1.54) | 0.040 | (0.0064) | 0.80 |
| 3. | 103-509 | *P. pratensis* × *P. angustifolia* | 5.6 | (0.27) | 0.132 | (0.0123) | 0.95 | 6.5 | (1.00) | 0.057 | (0.0088) | 0.86 |
| 4. | Mallard | *P. pratensis* | 6.8 | (0.38) | 0.148 | (0.0207) | 0.91 | 5.7 | (0.62) | 0.073 | (0.0090) | 0.91 |
| 5. | AKB449 | *P. pratensis* | 8.2 | (0.47) | 0.120 | (0.0163) | 0.89 | 6.6 | (1.94) | 0.035 | (0.0064) | 0.73 |
| 6. | Arrow | *P. pratensis* | 7.1 | (0.30) | 0.161 | (0.0187) | 0.94 | 8.9 | (1.45) | 0.042 | (0.0070) | 0.81 |
| 7. | A00TB-99 | *P. pratensis* × *P. arachnifera* | 8.7 | (0.50) | 0.159 | (0.0282) | 0.88 | 7.4 | (0.95) | 0.074 | (0.0133) | 0.83 |
| 8. | 1QG-38 | *P. pratensis* | 7.3 | (0.34) | 0.165 | (0.0218) | 0.92 | 9.9 | (1.22) | 0.068 | (0.0134) | 0.80 |
| 9. | AKB287 | *P. pratensis* | 6.7 | (0.35) | 0.138 | (0.0168) | 0.92 | 10.6 | (1.84) | 0.036 | (0.0061) | 0.75 |
| 10. | Royce | *P. pratensis* | 8.3 | (0.42) | 0.177 | (0.0299) | 0.90 | 9.6 | (1.20) | 0.077 | (0.0163) | 0.80 |
| 11. | A03TB-256 | *P. pratensis* × *P. arachnifera* | 7.5 | (0.33) | 0.151 | (0.0182) | 0.93 | 10.7 | (1.79) | 0.046 | (0.0097) | 0.71 |
| 12. | A03-TB-676 | *P. pratensis* × *P. arachnifera* | 9.6 | (0.40) | 0.184 | (0.0281) | 0.92 | 9.5 | (1.19) | 0.074 | (0.0152) | 0.78 |
| 12. | A00TB-101 | *P. pratensis* × *P. arachnifera* | 9.1 | (0.24) | 0.152 | (0.0123) | 0.97 | 11.0 | (1.33) | 0.063 | (0.0122) | 0.80 |
| 13. | AKB958 | *P. pratensis* | 8.0 | (0.39) | 0.145 | (0.0195) | 0.91 | 12.7 | (2.05) | 0.039 | (0.0079) | 0.73 |
| 13. | A03TB-417 | *P. pratensis* × *P. arachnifera* | 8.9 | (0.52) | 0.161 | (0.0296) | 0.87 | 12.5 | (2.09) | 0.037 | (0.0074) | 0.72 |
| 14. | 103-630 | *P. pratensis* × *P. angustifolia* | 10.9 | (1.77) | 0.054 | (0.0145) | 0.52 | 10.6 | (1.05) | 0.046 | (0.0058) | 0.89 |
| 14. | A03TB-708 | *P. pratensis* × *P. arachnifera* | 8.9 | (0.97) | 0.084 | (0.0171) | 0.70 | 13.1 | (1.07) | 0.063 | (0.0096) | 0.88 |
| 15. | A04TB-192 | *P. pratensis* × *P. arachnifera* | 9.1 | (0.55) | 0.097 | (0.0125) | 0.88 | 13.1 | (1.44) | 0.046 | (0.0072) | 0.83 |
| 15. | Cadet | *P. pratensis* | 8.1 | (0.24) | 0.148 | (0.0121) | 0.97 | 14.2 | (1.75) | 0.036 | (0.0057) | 0.79 |
| 16. | 1A4-529 | *P. pratensis* × *P. densa* | 8.7 | (0.97) | 0.081 | (0.0160) | 0.72 | 14.6 | (2.13) | 0.033 | (0.0060) | 0.73 |
| 16. | Midnight | *P. pratensis* | 9.8 | (0.35) | 0.167 | (0.0204) | 0.94 | 14.0 | (1.22) | 0.059 | (0.0093) | 0.88 |
| 17. | 1A4-221 | *P. pratensis* × *P. nemoralis* | 10.4 | (0.31) | 0.170 | (0.0182) | 0.95 | 14.3 | (1.51) | 0.049 | (0.0082) | 0.82 |
| 18. | Julius | *P. pratensis* | 8.0 | (0.56) | 0.130 | (0.0225) | 0.84 | 17.2 | (1.96) | 0.030 | (0.0046) | 0.78 |
| 19. | Broadway | *P. pratensis* | 9.3 | (0.26) | 0.181 | (0.0182) | 0.96 | 16.7 | (1.82) | 0.035 | (0.0053) | 0.80 |
| 20. | Pp H8510 | *P. pratensis* | 9.1 | (0.40) | 0.143 | (0.0179) | 0.92 | 17.0 | (1.95) | 0.036 | (0.0062) | 0.77 |
| 21. | Solar Green | *P. pratensis* × *P. arachnifera* | 8.1 | (0.22) | 0.210 | (0.0210) | 0.97 | 18.5 | (4.35) | 0.022 | (0.0065) | 0.43 |
| 22. | 1A3-1015 | *P. pratensis* | 8.2 | (0.21) | 0.162 | (0.0124) | 0.97 | 18.9 | (3.63) | 0.027 | (0.0073) | 0.53 |
| 23. | Fire & Ice | *P. pratensis* × *P. arachnifera* | 8.5 | (0.24) | 0.186 | (0.0184) | 0.96 | 18.7 | (3.79) | 0.024 | (0.0065) | 0.49 |
| 24. | 1A4-312 | *P. pratensis* × *P. angustifolia* | 10.1 | (0.69) | 0.109 | (0.0184) | 0.84 | 17.3 | (1.77) | 0.037 | (0.0056) | 0.80 |
| 25. | A03TB-795 | *P. pratensis* × *P. arachnifera* | 8.8 | (0.33) | 0.138 | (0.0144) | 0.94 | 18.7 | (2.23) | 0.034 | (0.0060) | 0.73 |
| 26. | A03TB-390 | *P. pratensis* × *P. arachnifera* | 9.8 | (0.48) | 0.115 | (0.0143) | 0.90 | 18.8 | (2.25) | 0.033 | (0.0059) | 0.74 |
| 27. | Thermal Blue | *P. pratensis* × *P. arachnifera* | 5.3 | (0.48) | 0.121 | (0.0181) | 0.87 | 31.1 | (2.47) | 0.024 | (0.0039) | 0.72 |

**Turfgrass quality of bluegrass entries**. Most of the bluegrasses tested in this trial had acceptable turfgrass quality over the two seasons of evaluation, with average turfgrass quality ratings from 4.6 to 6.8 (Table 3). The significance of these data is that drought-tolerant grasses can be developed that also produce high turfgrass quality. In fact, the highest average turfgrass quality rating was observed with entry 103-509, which also had the best drought tolerance in this trial (Table 1, Figs. 2 and 3).

Table 3. Turfgrass quality of bluegrass entries, averaged over several evaluations in the spring prior to initiating drought stress.

| | 2006 | 2007 | AVG |
|---|---|---|---|
| **Entry** | **Turfgrass quality** (1 to 9, with 9 = ideal) | | |
| 103-509 | 6.3 | 6.9 | 6.8 |
| 1QG-38 | 6.3 | 6.8 | 6.7 |
| Midnight | 6.5 | 6.6 | 6.6 |
| Bluestone | 6.8 | 6.3 | 6.4 |
| Royce | 6.5 | 6.3 | 6.4 |
| Cadet | 6.5 | 6.2 | 6.3 |
| AKB958 | 6.0 | 6.2 | 6.2 |
| Broadway | 6.8 | 5.9 | 6.1 |
| 1A4-312 | 6.3 | 6.0 | 6.1 |
| AKB287 | 6.0 | 6.1 | 6.1 |
| Julius | 6.5 | 5.9 | 6.1 |
| A03TB-390 | 6.3 | 5.9 | 6.0 |
| 1A3-1015 | 6.2 | 5.8 | 5.9 |
| Arrow | 6.3 | 5.7 | 5.9 |
| A00TB-99 | 6.0 | 5.8 | 5.8 |
| AKB449 | 6.0 | 5.6 | 5.7 |
| Mallard | 6.0 | 5.6 | 5.7 |
| A00TB-101 | 5.7 | 5.6 | 5.7 |
| 103-630 | 5.8 | 5.6 | 5.6 |
| A03TB-417 | 6.0 | 5.4 | 5.6 |
| 1A4-529 | 5.8 | 5.5 | 5.6 |
| A03TB-795 | 6.2 | 5.1 | 5.4 |
| 1A4-221 | 6.0 | 5.0 | 5.3 |
| Pp H8510 | 6.0 | 5.0 | 5.2 |
| A04TB-192 | 5.2 | 5.2 | 5.2 |
| Longhorn | 5.8 | 4.7 | 5.0 |
| Fire & Ice | 5.7 | 4.7 | 4.9 |
| A03TB-676 | 5.5 | 4.7 | 4.9 |
| A03TB-256 | 5.7 | 4.6 | 4.9 |
| Thermal Blue | 5.5 | 4.3 | 4.7 |
| A03TB-708 | 4.3 | 4.7 | 4.6 |
| Solar Green | 5.3 | 4.3 | 4.6 |
| **LSD (0.05)** | 0.6 | 0.5 | 0.4 |

## Key Findings

These results demonstrate that both KBG and HBG cultivars with improved drought tolerance can be identified. Selecting cultivars that have the ability to maintain green cover for long periods without supplemental irrigation could have a significant impact on seasonal water use. This can be especially beneficial in humid regions, where periodic rain can significantly reduce or even eliminate the need for irrigation. In those instances, the delay of drought stress symptoms would delay the need for supplemental irrigation and provide additional opportunity for rainfall to occur. Recent trials examining the irrigation requirements of some of the most drought tolerant and drought-sensitive grasses tested in this manner have indicated that up to 50% water savings can be realized when these drought-tolerant grasses are compared to some of the more drought-sensitive selections (K. Hignight, 2008, *unpublished data*).

Improvements in drought tolerance in KBG may not necessarily be realized by hybridizing *P. pratensis* with *P. arachnifera* germplasm, as many HBG entries were inferior to the best KBG entries. However, one hybrid between *P. arachnifera* and *P. angustifolia* did have excellent drought tolerance performance, suggesting that improvements in drought tolerance can be made via hybridization. However, these results demonstrate that any hybrids or traditional crosses within *P. pratensis* must still be screened under similar conditions to identify superior lines.



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