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Growth analysis of Kentucky bluegrass cultivars from six classification groups

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Abstract

Kentucky bluegrass (*Poa pratensis* L.) cultivars are diverse in their phenotype with a common classification system used to describe their growth habit but it is unclear why their growth differs. Growth analysis measurements have been used to explain growth rate differences among grass species and cultivars. The objective of this experiment was to study the growth of six commercially available Kentucky bluegrass cultivars from different growth habit classifications using classical growth analysis. Kentucky bluegrass seed was germinated and transplanted into cone-tainers and transferred to a growth chamber maintained at 25/15˚C (day/night) and a 12-h photoperiod. Thirty plants per cultivar were used with six whole plants of each cultivar harvested 8 weeks after transplanting and once per week for the next 4 weeks for a total of five harvests. Barvette HGT produced the largest plants, and Moonlight SLT produced the smallest plants by the end of the experiment, although the relative growth rate and absolute growth rate did not vary between the cultivars. Results from the growth analysis revealed that Moonlight SLT had the highest leaf area ratio (89.4 $cm^2\ g^{-1}$), specific leaf area (200.1 $cm^2\ g^{-1}$), and rhizome weight ratio (0.101 $g\ g^{-1}$), but the lowest stem weight ratio (0.120 $g\ g^{-1}$) and root weight ratio (0.338 $g\ g^{-1}$). Final plant weights and leaf area measurements were closely aligned with Kentucky bluegrass classification information. Unfortunately, classical growth analysis provided little insight into why some cultivars possess more aggressive growth characteristics or compact growth habits.

1 | INTRODUCTION

There are few studies that have researched the vegetative growth of Kentucky bluegrass (KBG) (*Poa pratensis* L.), also known as smooth-stalked meadowgrass. Burt and Christians (1990) reported differences in growth between low- and high-maintenance KBG cultivars with low-maintenance cultivars having greater rooting depth and mass and high-maintenance cultivars having wider and more leaves (Burt & Christians, 1990). Ebdon and Petrovic (1998) also studied KBG genotypes and they found that cultivars having wider leaves, a longer sheath length, and great leaf extension rate also have a higher evapotranspiration (ET). Later, Bonos et al. (2000) used the growth differences of diverse KBG spaced plants to develop a KBG classification system based on growth habit. Law et al. (2016) quantified the growth of KBG in the field

Abbreviations: AGR, absolute growth rate; LAR, leaf area ratio; LWR, leaf weight ratio; RGR, relative growth rate; RhW, dry weight of rhizomes; RhWR, rhizome weight ratio; RWR, root weight ratio; SLA, specific leaf area; SWR, stem weight ratio; ULR, unit leaf rate.

by measuring mowing frequency and dry matter yield (DMY) and reported that KBG cultivars are variable in their mowing requirements. Shearman et al. (2001) also studied the spread and sod tensile strength of KBG to help sod growers determine what cultivars to plant. These above studies collectively demonstrate in different ways the variable growth among KBG cultivars, but no study has explored and explained why growth rate is variable. Growth analysis may be a tool that might help explain the causes for these differences in growth among cultivars.

Hunt (1983, 1990, 2003) describes growth analysis as an examination of plant growth over time. Growth analysis considers all plant parts including leaves, stems, and roots with measurements including weight (fresh or dry), area (leaves or other parts of the plant), or volume (Hunt, 1990, 2003; Poorter, 2002). Measured weights and areas are then input into mathematical formulae to determine the growth of the plant over time (Hunt, 1990, 2003). Several commonly used measurements of plant growth used in growth analysis include absolute growth rate (AGR), leaf area ratio (LAR), leaf weight ratio (LWR), relative growth rate (RGR), specific leaf area (SLA), and unit leaf rate (ULR) as well as various ratios of plant morphology (roots, leaves, etc.). RGR is the most common measurement and assesses the growth over time relative to plant size, which contrasts to AGR which is a simple measure of dry weight increase over time (Hunt, 1978). The gain in plant weight per unit of leaf area is the ULR and is considered a proxy for growth efficiency or carbon-assimilation capacity while LAR estimates the ratio of photosynthesizing tissue to respiring tissue (Hunt, 1978). The leaf density or thickness of the plant is described by SLA, which is leaf area per unit of leaf weight, and LWR is a measure of the leafiness of the plant as a fraction of leaf weight per whole plant weight.

Several experiments have used growth analysis to examine the growth of cool-season grasses. Poorter and Remkes (1990) reported SLA is related to the RGR of grasses with species with higher SLA values also having a higher RGR. Poorter et al. (1995) studied grasses with low and high RGR values and concluded that high LAR and ULR led to higher RGR, regardless of nitrogen status. Garnier (1992) determined that annual grasses had higher RGR and higher ULR compared to perennial grasses. Grasses grown in high-input areas (habitats that are beneficial for growth) had a higher SLA than the grasses found in low-input areas (habitats that are poor in nutrient value) (Van Arendonk & Pooter, 1994). Additionally, Atkin et al. (1996) studied six *Poa* spp. from various altitudes and determined that the slow growth of some *Poa* species was due to a lower SLA. Variation in the SLA may be due to differences in organic nitrogen (N) compounds, (hemi)cellulose, lignin, or mineral content in leaves (Van Arendonk & Poorter, 1994).

Growth analysis has also been used to determine potential differences in growth between turfgrass species and cultivars.

Core Ideas

- Modern Kentucky bluegrass cultivars used for turfgrass had similar relative growth rates.
- Whole plant mass and leaf area measurements were consistent with Kentucky bluegrass growth habit classifications.
- Classical growth analysis provided little insight into why some cultivars grow more aggressively than others.

Elias and Chadwick (1979) studied the growth of turfgrass species including colonial bentgrass (*Agrostis capillaris* L.), four *Festuca* spp., perennial ryegrass (*Lolium perenne* L.), KBG, and roughstalk bluegrass (*Poa trivialis* L.). Among these species, differences in RGR were noted between species and also cultivars of colonial bentgrass and *Festuca rubra* (Elias & Chadwick, 1979). Cultivars of colonial bentgrass varied in their leaf, stem, and root weight ratios (Elias & Chadwick, 1979). While Elias and Chadwick (1979) studied six cultivars perennial ryegrass, three cultivars of colonial bentgrass, and five *F. rubra* cultivars, only a single KBG cultivar was examined. Within the genus *Zoysia*, species are known to vary in their growth habit and establishment rate (Patton et al., 2017). Patton et al. (2007) also reported that the AGR of zoysiagrass cultivars in a growth chamber closely followed trends in field establishment and that cultivars with lower AGR had higher LAR and SLA values (Patton et al., 2007).

Based on a literature review of the vegetative growth of KBG, no study has investigated why KBG cultivars grow differently. Conducting a classical growth analysis experiment on KBG genotypes should provide more information on the growth rate of different cultivars and the results should help give a better understanding on why certain cultivars grow faster than others. The objective of this experiment was to use classical plant growth analysis techniques to help explain differences in KBG seedling growth characteristics for commercially available cultivars from six contrasting classification groups.

2 | MATERIALS AND METHODS

2.1 | Growth analysis

Based on feedback from seed industry and turfgrass professionals, six commercially available KBG cultivars were selected for classical growth analysis in August 2022. Cultivars were selected that might have growth rate differences as described by marketing materials as either compact and

TABLE 1 Name and classification of Kentucky bluegrass (KBG) (*Poa pratensis*) cultivars used in the growth analysis experiment as well as their supplier.

Cultivar	Name of KBG classification[a]	Characteristics of classification and industry technical information[a,b]	Company
Sombrero	Limousine	High density, wear tolerant, and aggressive	DLF/Seed Research Oregon
Volt	Shamrock	Good turf quality, good sod strength, wear tolerant, and high strength rhizomes	Mountain View Seeds
Moonlight SLT	Elite Compact	Low growing, dark colored, salt tolerant	Pure Seed Testing
BlueNote	Compact-America	Higher density, low, compact turf; and aggressive	Mountain View Seeds
After Midnight	Compact-Midnight	Low, compact growth, slow growing, and heat tolerance	Jacklin Seeds
Barvette HGT	Unknown	Categorized with unknown specificity, aggressive	Barenbrug USA

[a](Greg Freyermuth, personal communication, February 2, 2022); Honig and Brilman (2018); Honig et al. (2018); Murphy et al. (2004).
[b]Anonymous (2022); Barenbrug USA (2021, 2022); DLF Pickseed (2020); Mountain View Seeds (2007a, 2007b).

slow-growing or aggressive and good sod producers (Table 1). Additionally, cultivars were selected to represent different classification types (Honig et al., 2018). Approximately 100 seeds were germinated in 100 × 15 mm Petri dishes (VWR Catalog Number: 25384-342) on 83-mm diameter blue blotter paper (PBB 325; Hoffman Manufacturing) for each cultivar. Fifty seedlings of each cultivar were transplanted from Petri dishes into 2.5-cm diameter, sand-filled Ray Leach conetainers (Stuewe & Sons, Inc.) when they reached 1–2 cm in height. The medium used for the cone-tainer rootzone was a United States Golf Association topdressing sand with 3 g kg^{-1} organic matter and 9 kg ha^{-1} P, 56 kg ha $^{-1}$ K, and a pH of 8.2.

Transplanted seedlings were grown in a growth chamber (PGR15; Controlled Environments Inc.) maintained at 25/15˚C (day/night) and a 12-h photoperiod of 500 μmol m^{-2} s^{-1} photosynthetically active radiation. Plants were fertilized daily after transplanting with 6 mL of a half-strength nutrient solution. The nutrient solution used, prior to diluting to half-strength, was a water-soluble fertilizer (20N–1.3P–15.8K; ICL Specialty Fertilizers) to provide the following (in mg/L): 150 N, 9.8 P, 119 potassium (K), 12 magnesium (Mg), 21 sulfur (S), 1.5 iron (Fe), 0.4 manganese (Mn) and zinc (Zn), 0.2 copper (Cu) and boron (B), and 0.1 molybdenum (Mo). Nitrate and ammoniacal sources of nitrogen were provided as 61% and 39% total N, respectively. The nutrient solution was adjusted to a pH range of 5.8–6.2.

The experimental design used frequent destructive harvests of replicated plants to measure mass by plant part and leaf area, which is a standard design in classical growth analysis experiments (Hunt, 1978). To reduce potential variability as suggested by Poorter and Garnier (1996), 30 plants with a similar size and tiller count within each cultivar were chosen 1 day prior to the first harvest from 50 transplanted seedlings to obtain a homogenous set (Whale et al., 1985). The plants were arranged randomly by cultivar and replicate plant number within harvest. Six whole plants of each cultivar were harvested 8 weeks after transplanting and once per week for the next 4 weeks for a total of five harvests. Eight weeks was chosen as the starting point because (1) plants were tillering, (2) rhizomes were beginning to be formed, and (3) plant growth resembled a "mature" morphology. At the first harvest, plants were approximately 2 to 3-tiller in size. After each harvest, either the trays were relocated inside the growth chamber, or the plants were relocated within the rack to minimize potential variation in environmental conditions and to minimize potential shading from adjacent plants.

Plants were separated into four fractions during destructive harvests: leaf blades, roots, rhizomes, and stems (the fraction remaining that consisted of mainly leaf sheaths). Leaf area was determined using scans of destructively harvested leaves and image analysis similar to Patton et al. (2007). Leaves were placed between two layers of non-reflective glass (Tru Vue Inc.) and scanned at 600 dpi (Perfection V850 Pro Photo Scanner; Epson Electronics Co.). Leaf scans were conducted immediately after harvest and image analysis (Image J 1.53a, National Institutes of Health) was used to determine the number of green pixels per image (hue 31–119; sat 0–255, brightness 0–255) (Schneider et al., 2012). Any large leaves or leaves prone to curling or folding were cut into smaller segments to better allow for pressing the leaves between the glass sheets. A calibration disk with a known area was also scanned and the data were converted from selected green pixels to leaf area (cm^2). Any mature leaves that were completely senesced were not included in leaf area or weight measurements. Root, rhizome, and stem tissues were washed with water to remove the majority of the sand and then all tissues (including leaves) were dried separately (at least 72 h at 60˚C) and weighed. Root

TABLE 2 Growth analysis abbreviations, meanings, units, formulae, symbols, and quantities used for *Poa pratensis* growth rate analysis.

Abbreviation	Meaning	Units	Formulae[a]
AGR, G	Mean absolute growth rate	mg day^{-1}	$(W_2 - W_1)/(t_2 - t_1)$
RGR, R	Mean relative growth rate	day^{-1}	$(\log_e W_2 - \log_e W_1)/(t_2 - t_1)$
ULR, E	Mean unit leaf rate[b]	g m^{-2} day^{-1}	$(W_2 - W_1)/(t_2 - t_1) \times [(\log_e L_{A2} - \log_e L_{A1})/(L_{A2} - L_{A1})]$
LAR, F	Mean leaf area ratio	cm^2 g^{-1}	$[(L_{A\,1}/W_1) + (L_{A2}/W_2)]/2$
SLA	Specific leaf area	cm^2 g^{-1}	$[(L_{A1}/L_{W1}) + (L_{A2}/L_{W2})]/2$
LWR	Leaf weight ratio		$[(L_{W1}/W_1) + (L_{W2}/W_2)]/2$
SWR	Stem weight ratio		$[(S_{W1}/W_1) + (S_{W2}/W_2)]/2$
RWR	Root weight ratio		$[(R_{W1}/W_1) + (R_{W2}/W_2)]/2$
RhWR	Rhizome weight ratio		$[(Rh_{W1}/W_1) + (Rh_{W2}/W_2)]/2$
K	Above-below allometry[c]		$((\log_e(L_{W2} + S_{W2})) - (\log_e(L_{W1} + S_{W1}))/(t_2 - t_1))/$ $((\log_e(R_{W2} + Rh_{W2})) - (\log_e(R_{W1} + Rh_{W}))/(t_2 - t_1))$
Symbol	Quantity		
W	Total dry weight of the plant		
T	Time in days		
L_A	Leaf area		
L_W	Dry weight of leaf blades		
S_W	Dry weight of stem		
R_W	Dry weight of roots		
Rh_W	Dry weight of rhizomes		

[a]Formulae from Radford (1967), Hunt (1990), and Hunt et al. (2002).

[b]Also known as mean net assimilation rate (NAR) by some authors.

[c]To calculate root-shoot allometry (K), we calculated the relative growth rate of the above ground portions of the plant (L_w, leaf blades and S_w, stems) and divided by the relative growth rate of the below ground portions of the plant (R_w, roots and Rh_W, rhizomes).

weights were calculated as the difference in dry weight before and after combustion in a muffle furnace (at least 3 h at 575°C) to account for sand remaining on the roots after washing.

2.2 | Data analysis

Data from the five harvests with six replicate plants per cultivar in each harvest were used to calculate values (Table 2) separately for each of the four time periods (i.e., period 1 = t_1–t_2, period 2 = t_2–t_3, etc.) for each of the six cultivars using the spreadsheet tool from Hunt et al. (2002). The growth analysis values obtained from each of the four separate time periods for each cultivar were then analyzed using PROC GLM (SAS Institute). An analysis of the data was performed with time period considered a random variable and cultivar fixed in the model (Bowley, 2015). Differences between cultivar means for a given growth analysis value were separated using Fisher's protected least significant difference ($\alpha = 0.05$) using the appropriate error term (McIntosh, 1983). Plant weights and leaf area on the final harvest date (t_5) were also analyzed, and the standard error of the mean was calculated for comparison using Prism (version 9.2; GraphPad Software Inc.).

3 | RESULTS

The mean growth analysis values for 10 different variables were measured for six cultivars (Table 3). Based on the growth rate calculations, there were no statistical differences between cultivars for RGR (p = 0.4632), AGR (p = 0.6491), ULR (p = 0.1594), and shoot:root allometry (K) (p = 0.7401). RGR values ranged from 0.0435 to 0.0608 day^{-1} and AGR ranged from 9.9 to 13.9 mg day^{-1}. Sombrero, classified as a "Limousine" type (Table 1), had the lowest numerical RGR value with 0.0435 day^{-1} and the lowest numerical K value at 0.99. Moonlight SLT, classified as a "Elite Compact" type, had the second highest numerical RGR value of 0.0584 day^{-1} and the lowest numerical AGR value of 9.9 mg day^{-1}.

LAR (p = 0.0280) and SLA (p = 0.0381) were different among the six cultivars and ranged from 76.2 to 89.4 cm^2 g^{-1} (LAR) and 170.6 to 200.1 cm^2 g^{-1} (SLA), respectively, with Moonlight SLT having the highest SLA and LAR (Table 3). BlueNote, classified as an "Compact-America" type, had the lowest SLA (Tables 1 and 3).

Leaf, root, stem, and rhizome weight ratio all varied (p < 0.0001) by cultivar. On average, KBG plants were composed of 43.6% leaves, 13.3% stems, 37.8% roots, and 5.3% rhizomes by weight (Table 3). Moonlight SLT had the

TABLE 3 Growth analysis mean values of Kentucky bluegrass (*Poa pratensis*) cultivars grown in a growth chamber maintained at 25/15˚C (day/night) and a 12-h photoperiod of 500 μmol m^{-2} s^{-1} photosynthetically active radiation. Sorted by highest in relative growth rate (RGR).

	Growth analysis									
Cultivar	RGR (day^{-1})	AGR (mg day^{-1})	ULR (g m^{-2} day^{-1})	LAR (cm^2 g^{-1})	SLA (cm^2 g^{-1})	LWR (g g^{-1})	SWR (g g^{-1})	RWR (g g^{-1})	RhWR (g g^{-1})	*K*
Volt	0.0608	12.5	10.32	81.1b	171b	0.476a	0.141a	0.365d	0.018d	1.18
Moonlight SLT	0.0584	9.9	6.65	89.4a	200a	0.441b	0.120c	0.338e	0.101a	1.48
After Midnight	0.0550	13.1	8.08	76.2b	184ab	0.412c	0.142a	0.378c	0.068b	1.25
BlueNote	0.0471	11.3	5.07	76.6b	171b	0.447b	0.131b	0.399b	0.024cd	1.25
Barvette HGT	0.0437	13.9	5.71	78.4b	188ab	0.417c	0.128b	0.412a	0.044c	1.26
Sombrero	0.0435	12.4	6.23	78.8b	189ab	0.423c	0.133b	0.378c	0.066b	0.99
Mean	0.0514	12.2	7.01	80.1	184	0.436	0.133	0.378	0.053	1.24
p-value	0.4632	0.6491	0.1594	0.0280	0.0381	<0.0001	<0.0001	<0.0001	<0.0001	0.7401

Note: Means within a column with a common letter are not significantly different according to Fisher's protected least significant difference ($\alpha = 0.05$).
Abbreviations: AGR, absolute growth rate; K, shoot:root allometry; LAR, leaf area ratio; LWR, leaf weight ratio; RGR, relative growth rate; RhWR, rhizome weight ratio; RWR, root weight ratio; SLA, specific leaf area; SWR, stem weight ratio; ULR, unit leaf rate.

highest rhizome weight ratio (RhWR) at 0.101, but the lowest stem weight ratio (SWR) and root weight ratio (RWR) at 0.120 g g^{-1} and 0.338 g g^{-1}, respectively. After Midnight, classified as a "Compact-Midnight" type, had one of the highest SWR (0.142 g g^{-1}), but one of the lowest LWRs at 0.412 g g^{-1}. Barvette HGT, while formally classified as an "Unknown" type, but anecdotally has been observed to be highly aggressive in the field, had the highest numerical AGR of 13.9 m day^{-1} and the highest RWR of 0.412 g g^{-1}.

While AGR values were not statistically different over time period via ANOVA ($p = 0.6491$, Table 3) or via a comparison of their growth rate slopes ($p = 0.1303$, Figure 1), plant size did vary in this experiment. Figure 2 shows a comparison of the weights and leaf area across all six cultivars at the final harvest rather than their mean relative weight ratios within cultivar across time period (Table 3). Barvette HGT had the highest leaf, stem, root, and whole plant weights as well as leaf area (Figure 2). After Midnight had leaf, stem, and rhizome weights as well as leaf area similar to Barvette HGT. Sombrero was the highest in rhizome weight but was not different than After Midnight, Barvette HGT, or Moonlight SLT. Moonlight SLT had the lowest leaf, stem, and whole plant weights, but the second highest rhizome weight (Figure 2).

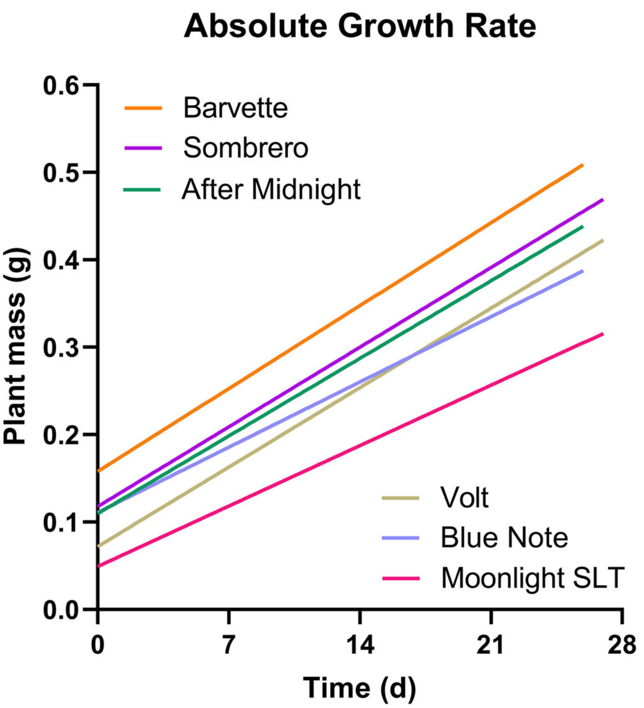

FIGURE 1 The absolute growth rate (whole plant mass over time) for six Kentucky bluegrass (*Poa pratensis*) cultivars. The slope of the line (AGR) was not different ($p = 0.1303$) among cultivars.

4 | DISCUSSION

There were no differences in RGR, AGR, ULR, and K and relatively few differences in SLA and LAR between cultivars. This is similar to Elias and Chadwick (1979), who found no differences in RGR between perennial ryegrass and small differences between colonial bentgrass cultivars and three species of fine fescue: strong creeping red fescue (*F. rubra* L. ssp. *rubra* Gaudin), slender creeping red fescue [*F. rubra* L. ssp. *littoralis* (G. Mey.) Auquier], and Chewings fescue (*F. rubra* L. ssp. *commutata* Gaudin). Elias and Chadwick (1979) noted that the lack of differences is likely due to both growing the grasses under ideal conditions and the relatively small diversity within commercially bred cultivars. The lack of differences among KBG cultivars in this research may be due to the fact that no forage or older cultivars were tested, nor were plants subjected to stresses like limited nutrient levels.

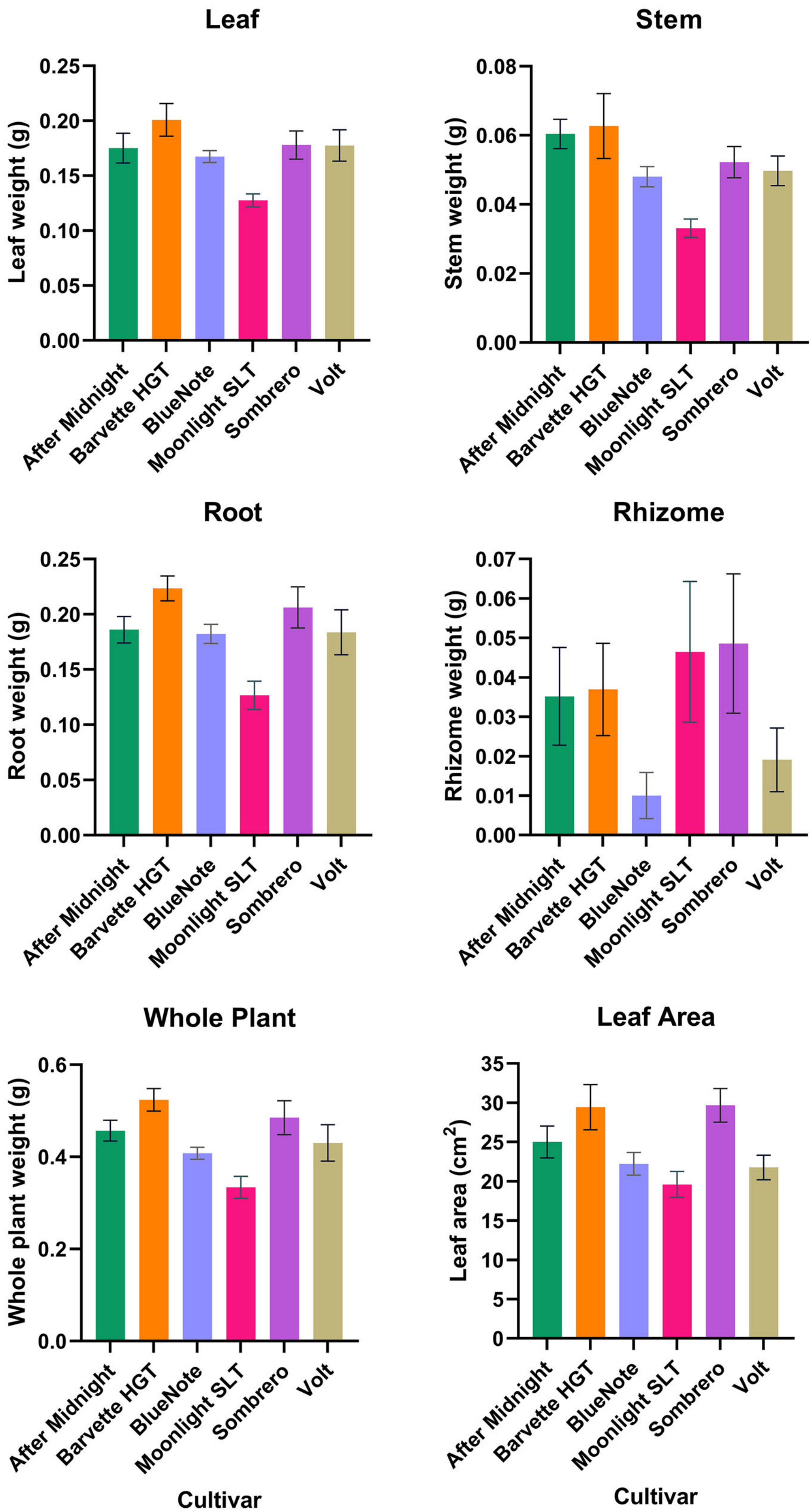

FIGURE 2 Leaf, stem, root, and rhizome weights as well as a combined whole plant weight and leaf area for Kentucky bluegrass (*Poa pratensis*) cultivars on the final harvest date (day 27). The standard error of the mean is shown for each cultivar ($n = 6$).

Moonlight SLT had the highest LAR, SLA, and RhWR, but was the lowest in SWR and RWR (Table 3). Poorter and Remkes (1990) reported that increased SLA leads to an increase in RGR. While Moonlight SLT had the highest SLA, its RGR was only numerically higher and not statistically higher than other cultivars. Further, Atkin et al. (1996) reported that slow growth in the field was not necessarily due to a lower rate of photosynthesis (estimated as ULR) among *Poa* species. A comparison of final plant weights and leaf area among cultivars (Figure 2) helps to demonstrate that while Moonlight SLT had a high ratio of photosynthesizing to respiring material (LAR) (Table 3), it was smaller than other cultivars in plant size (weight and leaf area) (Figure 2), except with respect to rhizome production. This low final plant weight helps to understand why this cultivar is described in company technical documents as low growing with the capacity to be mown at lower heights (Anonymous, 2022) and classified as an "Elite Compact" (Greg Freyermuth, personal communication, February 2, 2022). Law et al. (2016) confirmed that compact KBG cultivars require less mowing and have a reduced DMY.

Barvette HGT had the highest RWR, had the highest numerical AGR (Table 3), and produced plants with the greatest leaf, stem, and root weights as well as leaf area (Figure 2). The whole plant weight and leaf area of Barvette HGT was similar to Sombrero (Figure 2) at the end of the study. While AGR was similar among cultivars, larger Barvette HGT and Sombrero plants may be indicative of the reputation of these cultivars as both are considered to be high performers for trafficked athletic fields (Park & Murphy, 2018; Pease et al., 2020) and characterized as aggressive and wear tolerant in industry technical information (Barenbrug USA, 2022; DLF Pickseed, 2020).

BlueNote had the lowest SLA of the cultivars. Van Arendonk and Poorter (1994) noted that plants with low SLA are more successful in nutrient-poor environments. BlueNote is known for its ability to maintain high-quality turf in a low-input situation and is among cultivars recommended for high-quality turf when water conservation, reduced fertility, and traffic, heat, and drought stress tolerances are desirable (Alliance for Low Input Sustainable Turf, 2023). However, more research is needed to determine if SLA is a good predictor of field performance in low-input scenarios among other KBG cultivars.

The results of the growth analysis showed both similarities and differences among the six KBG cultivars. However, there were no significant differences between cultivars for RGR, AGR, ULR, and K. The lack of statistical differences may be due to lack of replication in this study or the similar genetics and nutrient-rich culture mentioned previously. Poorter and Garnier (1996) suggested eight plants per cultivar per harvest date, but only six were used in this study due to growth chamber space and labor limitations associated with the destructive harvests. Increasing replication would possibly increase the degrees of freedom and help in mean separation. Alternatively, statistical power could be increased by narrowing down the list of cultivars using preliminary data to allow for more plants per harvest without increasing the total harvest labor.

5 | CONCLUSION

While there were no differences in RGR among cultivars, plant weights were different, and this helps to explain why some cultivars are classified as aggressive or compact types. Final plant weight and leaf area measurements closely aligned with industry KBG classification information. Unfortunately, classical growth analysis provided little insight into why cultivars have aggressive growth characteristics or compact growth habits. Designing future growth analysis experiments using germplasm with more diverse genetic backgrounds may allow for a better understanding of the reasons why some cultivars grow differently than others.

AUTHOR CONTRIBUTIONS

Amanda J. Folck: Conceptualization; data curation; formal analysis; investigation; validation; writing—original draft; writing—review and editing. **Cale A. Bigelow**: Supervision; writing—review and editing. **Yiwei Jiang**: Supervision; writing—review and editing. **Aaron J. Patton**: Conceptualization; formal analysis; funding acquisition; investigation; methodology; project administration; resources; supervision; visualization; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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