Ornamental Grass Growth Response to Three Shade Intensities[1]

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Abstract

Growth of perennial quaking grass (*Briza media* L.), 'Red Baron' Japanese bloodgrass (*Imperata cylindrica* (L.) Beauv. 'Red Baron'), river oats (*Chasmanthium latifolium* (Michx.) Yates), 'Hameln' dwarf fountain grass (*Pennisetum alopecuroides* (L.) Spreng. 'Hameln'), and 'Big Blue' monkeygrass (*Lirope muscari* (Decne.) L.H. Bail. 'Big Blue') in 0%, 30%, or 60% shade was evaluated in container and in-ground experiments conducted over two growing seasons. Shade intensity did not affect plant height of any species grown in containers in 1997 or those grown in the ground that were planted and harvested in 1998. In 1997, width of containerized perennial quaking grass increased and width of containerized dwarf fountain grass decreased with increasing shade. In 1998, width of containerized Japanese bloodgrass increased and width of containerized dwarf fountain grass decreased with increased shade. Container-grown river oats shoot and root dry weight increased with shade intensity in 1998. Root to shoot (R/S) ratio decreased linearly with shade intensity for containerized river oats in 1997. Height of in-ground Japanese bloodgrass was not affected by shade intensity at any harvest time; however, height of perennial quaking grass increased and height of river oats and monkeygrass decreased as shade intensity increased regardless of harvest time. Few differences in plant width among shade treatments occurred for in-ground plants. Shoot dry weights for in-ground plants generally decreased with increasing shade intensity. Climatic differences may account for the variability in plant growth between the two years of the study.

Index words: container production, landscape plants, light.

Species used in this study: perennial quaking grass (*Briza media* L.); 'Red Baron' Japanese bloodgrass (*Imperata cylindrica* (L.) Beauv. 'Red Baron'); river oats (*Chasmanthium latifolium* (Michx.) Yates); 'Hameln' dwarf fountain grass (*Pennisetum alopecuroides* (L.) Spreng. 'Hameln'); 'Big Blue' monkeygrass (*Lirope muscari* (Decne.) L.H. Bail. 'Big Blue').

Significance to the Nursery Industry

Most information about grasses comes from systematic botany, which describes plant taxonomy and native habitats (6, 11, 19, 20). Very few studies have evaluated the horticultural aspects of ornamental grasses including production methods and landscape uses. Currently, site selection recommendations for ornamental grasses are largely based on the replication of native habitats of those grasses. While these habitats may be optimal for plant growth and survival, some grasses might perform well under other environmental conditions. Our study was conducted over a two-year period in containers and in the field. Plant height was not affected by shade intensity in any of the species grown in containers. Shade effects on plant width varied by year on all containerized species. Height of in-ground Japanese bloodgrass was not affected by shade intensity at any harvest time; however, height of perennial quaking grass increased and height of river oats and monkeygrass decreased as shade intensity increased regardless of harvest time. Few differences in plant width among shade treatments occurred for in-ground plants. We attribute differences in plant responses between years to differences in climatic conditions.

Introduction

Plants typically respond to dense shade in several ways. Commonly, leaf-area ratio (LAR, leaf area / total plant dry weight), leaf-to-stem mass ratio, and stem length increase, but specific leaf weight (SLW, leaf dry weight / leaf area), plant dry weight, leaf-blade thickness, and root growth relative to shoot growth frequently decrease in shade compared to plants in higher light levels (3, 7, 12). Kephart et al. (14) determined that shoot dry weight of three C_3 and two C_4 grasses decreased with increased shade for all species, but shoot number decreased in tall fescue (*Festuca arundinacea* (L.) Schreb, 'Kentucky-31') and big bluestem (*Andropogon gerardii* Vitm. 'Kaw') with increased irradiance. Reduced light intensities can produce enlarged stems as a result of the partitioning of photosynthates by the plant (9). However, in dense shade, reduced photosynthate production limits plant development. In a turfgrass study with bermudagrass (*Cynodon dactylon* (L.) Pers.), phenotypically diverse clones responded to reduced light intensity with shorter leaves, shorter internodes, and reduced dry weights (10). Larger LAR and smaller SLW occurred in all grasses with increased shade (14).

Cruz (8) found that above-ground biomass and leaf area index of a C_4 tropical grass did not diminish by decreasing photosynthetically active radiation (PAR) up to 80%. This may be explained by higher N levels in the soil due to higher rates of mineralization of soil N under shaded conditions (8). The shaded soil surface-litter interface, with higher soil moisture than in open areas, appears to be conducive to higher N mineralization. Under low N fertility, shade can stimulate shoot dry matter yields and increase shoot N concentration (12). Increased shade also commonly reduces root and rhizome growth proportionately more than shoot growth (9). Patterson (16) found that grasses may also produce fewer leaves, tillers and rhizomes when shaded.

Light intensity may decrease as much as 90 to 95% with extensive cloud or tree cover (2). Ornamental grasses that can survive and retain their visual qualities in densely shaded

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environments would be a beneficial landscape alternative to other herbaceous perennials. Determining the shade tolerance of ornamental grasses will allow their incorporation in landscape niches that are typically hard to fill. The objective of this study was to determine the growth response of five container and in-ground perennial grasses under three shade intensities.

Materials and Methods

1997. Liners of five ornamental grasses, perennial quaking grass, Japanese bloodgrass, river oats, dwarf fountain grass and monkeygrass, were planted in containers and in the ground on June 18, 1997. The perennial quaking grass, river oats and monkeygrass are C_3 plants while the Japanese bloodgrass and dwarf fountain grass are C_4 plants (6, 11, 20). The container grown plants were potted in 11.4 liter (#3) containers with a pine bark:peat:sand substrate (3:1:1 by vol) amended with 4.3 kg/m^3 (8.9 lb/yd^3) 17N–3.6P–10K (17–7–12) slow release fertilizer (Osmocote, Scotts Co., Marysville, OH), 0.9 kg/m^3 (1.5 lb/yd^3) trace elements (Micromax, Scotts Co.), and 1.8 kg/m^3 (3 lb/yd^3) dolomite. Container substrate pH was 5.5. The soil for the in-ground plants was a Norge loam (fine-silty, mixed, thermic Udic Paleustols), with a pH of 7.0, and plants were spaced on 61 cm (24 in) centers. The plants were grown in 0%, 30%, and 60% reduced photosynthetic photon flux (PPF). The shade treatments were created by using woven shade cloth on hoop house frames. The plants were hand watered as needed throughout the growing season. All containers and in-ground plots were hand weeded.

Plant height and width were measured at planting and just prior to dormancy after one (5 months) or two growing seasons (17 months). Height was measured from the substrate or soil surface to the highest apparent canopy point. Width was measured at crown level for the bunch-type species (perennial quaking grass, river oats, dwarf fountain grass) and at ground level for the stoloniferous species (Japanese bloodgrass and monkeygrass). Roots and shoots of the container plants and shoots of the in-ground plants were harvested after the plants were dormant. Harvested shoots of all plants and washed roots from container plants were dried at 65C (149F) for 7 days then weighed. Root to shoot (R/S) ratio was calculated as root dry weight / shoot dry weight. Maximum PPF measured at plant height was 1443, 1030, and 617 µmol/m^2/s, or 0%, 29%, and 57% shade for the 0%, 30%, and 60% treatments, respectively.

1998. The experiment was repeated as previously described, except the grasses were planted on May 10, 1998, and all plants were harvested five months later, just prior to dormancy. Maximum PPF measured at plant height was 1598, 1034, and 658 µmol/m^2/s, or 0%, 35%, and 59% shade for the 0%, 30%, and 60% treatments, respectively.

Statistics. The experimental design each year and for each planting method (container and in-ground) was a completely randomized design with five replications. Analysis of variance procedures (GLM) and trend analyses by species were performed on all data using SAS Statistical Software (SAS Institute, Cary, NC).

Table 1. Height and width of five ornamental grasses after one growing season in 0, 30 and 60% shade in containers.

Species / Shade treatment	Height (cm) 1997	Height (cm) 1998	Width (cm) 1997	Width (cm) 1998
Perennial quaking grass				
0%	20.1	5.7	11.0	7.3
30%	15.4	8.8	12.4	10.6
60%	28.5	11.5	20.0	8.4
Linear	NS[z]	**	**	NS
Quadratic	NS	NS	NS	**
Japanese bloodgrass				
0%	39.5	35.7	20.9	19.9
30%	39.6	40.0	22.2	22.9
60%	46.0	39.0	23.5	23.5
Linear	NS	NS	NS	*
Quadratic	NS	NS	NS	NS
River oats				
0%	56.2	54.6	10.6	9.8
30%	60.6	59.4	10.8	11.9
60%	47.4	54.4	10.9	10.8
Linear	NS	NS	NS	NS
Quadratic	NS	*	NS	NS
Dwarf fountain grass				
0%	48.0	48.0	11.5	9.3
30%	51.6	50.2	9.9	8.9
60%	52.7	55.6	6.7	5.8
Linear	NS	*	**	**
Quadratic	NS	NS	NS	NS
Monkeygrass				
0%	8.2	8.7	6.2	6.3
30%	11.1	11.4	8.2	5.0
60%	10.1	12.3	7.0	7.3
Linear	NS	*	NS	NS
Quadratic	NS	NS	NS	*

[z]NS, *, ** Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

Results and Discussion

Container plants. In 1997, shade intensity did not affect plant height regardless of species (Table 1). In 1998, height of perennial quaking grass, dwarf fountain grass and monkeygrass increased linearly with increasing shade intensity, while river oats had a quadratic relationship between height and shade intensity such that plants in 30% shade were taller than those in 0% or 60% shade. Width of perennial quaking grass increased linearly while width of dwarf fountain grass decreased linearly with increasing shade intensity in 1997. In 1998, perennial quaking grass width had a quadratic response to shade intensity such that plants in 30% shade were widest and those in 0% shade were narrowest. Monkeygrass also responded quadratically to increasing shade, but monkeygrass plants in 30% shade had the smallest diameters and those in 60% shade were largest in diameter. Japanese bloodgrass had a positive linear relationship while dwarf fountain grass had a negative linear relationship between plant width and shade intensity in 1998.

In 1997, quadratic relationships existed between shoot dry weight and shade intensity for perennial quaking grass and river oats such that plants receiving 30% shade had the smallest shoot dry weights while those receiving 60% shade had the largest (Table 2). Quadratic relationships also occurred between shoot dry weight and shade intensity for dwarf fountain grass and monkeygrass, but plants of these species receiving 30% shade had the largest shoot dry weights compared to plants of those species in other shade treatments. In

Table 2. Shoot dry weight, root dry weight and root to shoot (R/S) ratio of five ornamental grasses after one growing season in 0, 30 and 60% shade in containers.

Species Shade treatment	Shoot weight (g)		Root weight (g)		R/S ratio	
	1997	1998	1997	1998	1997	1998
Perennial quaking grass						
0%	17.2	0.7	6.1	1.7	0.4	2.2
30%	10.0	13.9	3.5	6.3	0.4	0.5
60%	29.9	18.0	14.5	6.5	0.5	0.4
Linear	**[z]	**	**	*	NS	**
Quadratic	**	NS	**	NS	NS	**
Japanese bloodgrass						
0%	30.9	24.1	6.2	3.5	0.2	0.2
30%	30.9	19.3	7.3	4.1	0.2	0.2
60%	23.9	25.7	6.0	3.8	0.2	0.1
Linear	NS	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	**
River oats						
0%	22.4	16.4	48.3	10.3	2.2	0.7
30%	20.0	19.4	41.7	13.6	2.1	0.7
60%	28.4	22.2	44.9	16.6	1.6	0.7
Linear	*	NS	NS	*	*	NS
Quadratic	*	NS	NS	NS	NS	NS
Dwarf fountain grass						
0%	22.7	55.3	27.3	15.7	1.2	0.3
30%	35.7	64.9	41.1	27.0	1.2	0.4
60%	22.5	70.8	29.8	21.8	1.3	0.3
Linear	NS	*	NS	*	NS	NS
Quadratic	**	NS	**	*	NS	**
Monkeygrass						
0%	5.8	2.1	13.8	1.7	2.4	0.8
30%	17.0	1.3	43.2	2.3	2.6	1.8
60%	8.6	2.3	15.2	3.2	1.8	1.3
Linear	NS	NS	NS	NS	NS	**
Quadratic	**	NS	**	NS	NS	**

[z]NS, *, ** Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

1998, shoot dry weight of perennial quaking grass and dwarf fountain grass increased linearly with shade intensity, but Japanese bloodgrass, river oats and monkeygrass shoot dry weights were not affected by shade intensity. Perennial quaking grass root dry weight responded quadratically to shade intensity in 1997 such that root dry weight was smallest in 30% shade and largest in 60% shade. A quadratic relationship between root dry weight and shade intensity also existed for dwarf fountain grass and monkeygrass in 1997, but plants in 30% shade had the greatest and plants in 0% shade had the smallest root dry weights for each of these species. Root dry weight of perennial quaking grass and river oats increased linearly in 1998 with increased shade intensity. A quadratic relationship between root dry weight and shade intensity occurred for dwarf fountain grass in which plants in the 30% shade had the largest and plants in 0% shade had the smallest root dry weights in 1998. The river oats R/S ratio decreased linearly with increased shade intensity in 1997. In 1998, perennial quaking grass R/S ratio decreased quadratically, while dwarf fountain grass and monkeygrass had a quadratic relationship between R/S ratio and shade intensity such that plants of each species in 30% shade had the largest R/S ratio. Japanese blood grass R/S ratio was quadratically related to shade intensity but plants in 0% and 30% shade had greater R/S ratios than those in 60% shade.

In-ground plants. A quadratic relationship existed between height and shade intensity for perennial quaking grass and river oats that were planted in June 1997 and harvested five months later (Table 3). Perennial quaking grass plants were largest in 30% shade and smallest in 0% shade while river oats were largest in 0% shade and smallest in 30% shade. In contrast, a decreasing linear relationship occurred for monkeygrass between height and shade intensity for plants that were planted in June 1997 and harvested five months later. An increasing quadratic relationship occurred between height and shade intensity for dwarf fountain grass harvested 17 months after a June 1997 planting date. Perennial quaking grass plant width increased linearly but dwarf fountain grass plant width decreased linearly as shade intensity increased for plants planted in June of 1997 and harvested five months later. In contrast, dwarf fountain grass planted in June of 1997 and harvested 17 months after planting had a quadratic relationship between width and shade intensity such that plants in 0% shade were widest and those in 30% shade were narrowest. There were no differences in plant height or width among the various shade treatments for any species planted in May of 1998 and harvested five months later (data not shown).

A quadratic relationship between shoot dry weight and shade intensity existed for perennial quaking grass harvested

Table 3. Height and width of five ornamental grasses grown under 0, 30 and 60% shade in the ground and harvested 5 or 17 months after planting in June 1997.

	Height (cm)		Width (cm)	
	Time to harvest		Time to harvest	
Species Shade treatment	5 months	17 months	5 months	17 months
Perennial quaking grass				
0%	12.0	24.6	9.6	13.4
30%	16.5	25.0	10.7	12.0
60%	12.6	29.2	14.7	13.8
Linear	NS[z]	NS	*	NS
Quadratic	*	NS	NS	NS
Japanese bloodgrass				
0%	38.3	72.8	31.4	83.0
30%	43.2	77.4	34.4	92.6
60%	44.2	76.6	29.2	70.4
Linear	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS
River oats				
0%	51.5	83.2	9.2	13.8
30%	20.4	45.4	8.6	10.4
60%	29.4	64.6	7.4	12.4
Linear	*	NS	NS	NS
Quadratic	*	NS	NS	NS
Dwarf fountain grass				
0%	45.1	61.0	9.5	12.8
30%	54.6	71.4	8.1	10.4
60%	41.4	72.0	5.5	11.4
Linear	NS	**	**	NS
Quadratic	NS	*	NS	*
Monkeygrass				
0%	5.1	17.3	4.7	6.3
30%	3.1	15.2	4.1	8.6
60%	2.1	16.5	3.9	8.0
Linear	**	NS	NS	NS
Quadratic	NS	NS	NS	NS

[z]NS, *, ** Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

Table 4. Shoot dry weight of five ornamental grasses grown two growing seasons in 0, 30 and 60% shade in the ground.

	Shoot dry weight (g)		
	Planting date (Time to harvest)		
Species Shade treatment	June 1997 (5 months)	June 1997 (17 months)	May 1998 (5 months)
Perennial quaking grass			
0%	8.3	68.7	19.2
30%	10.8	62.9	23.5
60%	4.6	42.8	24.4
Linear	*[z]	NS	NS
Quadratic	**	NS	NS
Japanese bloodgrass			
0%	16.8	157.9	42.9
30%	11.2	191.9	21.9
60%	10.1	101.5	37.3
Linear	NS	NS	NS
Quadratic	NS	NS	NS
River oats			
0%	26.6	184.3	42.7
30%	9.8	20.6	17.7
60%	24.2	101.7	35.7
Linear	NS	NS	NS
Quadratic	**	**	**
Dwarf fountain grass			
0%	23.8	187.7	99.0
30%	17.6	266.2	93.3
60%	5.9	164.7	36.4
Linear	**	NS	**
Quadratic	NS	NS	**
Monkeygrass			
0%	3.9	5.7	16.5
30%	3.3	2.5	12.6
60%	1.5	0.4	5.4
Linear	**	NS	**
Quadratic	NS	NS	NS

[z]NS, *, ** Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

five months after planting in June 1997 such that plants in 30% shade had the largest and those in 60% shade had the smallest shoot dry weight (Table 4). Similarly, a quadratic relationship between shoot dry weight and shade intensity occurred for river oats regardless of planting and harvest dates. River oats plants in 30% shade had the smallest and those in 0% shade had the largest shoot dry weight at all planting and harvest dates. Dwarf fountain grass shoot dry weight decreased linearly with increased shade intensity for the harvest five months after planting in 1997, but dwarf fountain grass shoot dry weight decreased quadratically with increased shade intensity for the harvest five months after planting in 1998. Shoot dry weight of monkeygrass decreased linearly with increased shade intensity for harvests five months after planting in 1997 and in 1998.

Kephart et al. (14) found that irradiance regime did not significantly influence shoot length in 'Kentucky 31' tall fescue, reed canarygrass (*Phalaris arundinacea* L. 'Vantage'), deertongue grass (*Panicum clandestinum* L. 'Tioga'), switchgrass (*Panicum virgatum* Michx. 'Cave-in Rock') or big bluestem (*Andropogon gerardii* Vit 'Kaw'). We also found that shade treatments did not significantly affect height of container grown plants in 1997 or in-ground plants that were planted and harvested in 1998. Plant height is believed to increase with increasing shade until photosynthate production declines (4, 13, 15). Santelmann et al. (18) reported that 60% shade suppressed height of yellow foxtail (*Setaria lutescens* (Weigel.) Hubb.). Patterson (15) reported that 40% shade increased itchgrass (*Rottboellia exalta* (L.) L.F.) height, but greater shading reduced plant height. Our trends toward quadratic relationships or negative linear relationships between height and shade intensity for some species planted in 1997 might, therefore, be attributed to limited photosynthates due to the increased shade.

Bubar and Morrison (5) found that green foxtail (*Setaria viridis* (L.) Beauv.) and yellow foxtail, both C_4 species, had fewer tillers in shade than sun. These findings are supported, in part by our results. The width of dwarf fountain grass (C_4 species) decreased with shade intensity. In contrast, river oats, another C_4 species, was wider with increased shade intensity. Allard et al. (1) showed that low irradiance reduced the number of tillers per plant in tall fescue, a C_3 species. Our C_3 species, perennial quaking grass, river oats and monkeygrass, in containers generally increased in width with increased shade, but there were few differences in plant width for these species grown in the ground under various shade intensities.

A positive linear relationship between dry weight and shade intensity was reported for St. Augustinegrass (*Stenotaphrum secundatum* (Walt.) Kuntze) and carpetgrass (*Axonopus compressus* (Sw.) Beauv.) (17). However, Barrios et al. (2) found that generally lawngrass yield decreased with increasing shade for 'Oklawn' centipedegrass (*Eremochloa ophiuroides* (Munro.) Hack.), 'Floratam' St. Augustinegrass, 'Floratine' St. Augustinegrass, and 'Emerald' zoysiagrass (*Zoysia japonica* (Stued.) x *Z. tenuifolia* (Willd.)). There were also differences in our study, with a quadratic relationship between shoot dry weight and shade intensity for dwarf fountain grass and monkeygrass grown in containers in 1997, while container-grown dwarf fountain grass shoot dry weight increased linearly in 1998. Shoot dry weight generally decreased with increased shade intensity for in-ground plants.

Samarakoon et al. (17) found lower root weight and lower R/S ratios in St. Augustinegrass, carpetgrass, and kikuyugrass (*Pennisetum clandestinum* Hochst. ex Chiov.) grown in shade, and Allard et al. (1) found lower R/S ratios in tall fescue under increasing shade. Our study showed greater root dry weights for container grown plants in the shade treatments compared to no shade for perennial quaking grass, river oats and dwarf fountain grass in 1998. The 1998 container planting of perennial quaking grass, river oats, dwarf fountain grass and monkeygrass had a quadratic response to shade for R/S ratio while the 1997 container grown river oats R/S ratio had a negative linear response to shade.

Turfgrass growth responses to shade include decreased shoot dry weight, root and rhizome growth, R/S ratio, horizontal growth habit and increased plant height (9). The response of the species in our study did not always correspond to the general findings for turfgrass species. Also, species with the same photosynthetic pathway did not always respond to shade in the same way.

In addition to the parameters measured in these studies, other plant characteristics that might be affected by shade intensity include color, lodging, rhizome production, and flowering. We observed no differences in foliage color among the different shade intensities within any species tested. Lodging was not observed for any species in any shade intensity. We did not measure rhizome production; however, plant width should provide an indication of rhizome length for rhizomatous species. We did determine the number of days to flowering for each species and shade environment and found no significant difference in the number of days to flowering among the shade treatments in any species (data not shown).

While there were differences in some of the growth parameters measured, these differences varied by year. Climatic conditions of these two years were quite different. The first year was unusually cool and wet for the region. The second year was unusually hot, and there were extended periods without natural precipitation. We did irrigate during both years; however, irrigation does not compensate for lost cloudy days in which humidity is generally higher and temperatures are reduced. These climatic differences may account for the variability in plant responses between the two years. Yet, based on our observations, we would suggest that any of the species tested should perform reasonably well in conditions similar to the shade exposures tested.

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