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ELEVATED CO_2 AND TEMPERATURE EFFECTS ON PASPALUM AND ARACHIS FORAGES.

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ABSTRACT

Long-term effects of elevated carbon dioxide (CO_2) and elevated temperature on growth processes of bahiagrass (Paspalum notatum Flugge) and rhizoma peanut (Arachis glabrata Benth.) were evaluated. Forages were established and grown in 27-m long temperature-gradient greenhouses constructed over a natural field soil. Treatments were two CO_2 levels, 350 or 700 vpm CO_2, and four temperature sectors (0, 1.5, 3.0, and 4.5 °C above ambient). Shoot emergence, ground cover, leaf and canopy assimilation, rate of leaf appearance, and dry matter accumulation were measured. Increasing temperature accelerated plant establishment and increased early plant dry matter accumulation, leaf area, and leaf appearance rate. Doubling CO_2 increased biomass accumulation by 14 and 52%, and increased leaf photosynthesis by 18 and 41%, respectively for bahiagrass and rhizoma peanut. Elevated CO_2 increased single-cut establishment-year herbage yield of bahiagrass from 321 to 376 g m^{-2} and rhizoma peanut from 318 to 384 g m^{-2}, increases of 17 and 21%, respectively. Growth and assimilation of both species showed no negative effects of elevated temperature.

KEYWORDS

Bahiagrass, perennial peanut, carbon dioxide, elevated temperature, herbage yield, growth, photosynthesis.

INTRODUCTION

Global climate change appears to be increasingly more probable, given the increases in atmospheric CO_2 associated with fossil fuel burning and deforestation. Perennial forage species cover large land areas and serve an important role as sources and sinks for atmospheric C (Hall and Scurlock, 1991). Therefore, it is important to understand the impacts of increased CO_2 and elevated temperature on productivity and nutritive composition of perennial grassland species.

The two species studied include bahiagrass, a C_4 perennial pasture grass predominant in the southeastern USA, and rhizoma peanut, a perennial C_3 forage legume with much potential for tropical and subtropical regions (Prine et al., 1981). Both species sequester considerable carbon in underground rhizomes or surface-level stolons, a feature of interest to long-term C balance dynamics of terrestrial ecosystems. The specific objective of this study was to quantify the long-term effects of elevated temperature at ambient vs. elevated CO_2 on photosynthesis, growth, herbage production, and dry matter allocation among plant components including rhizomes/stolons of bahiagrass and rhizoma peanut.

MATERIALS AND METHODS

This experiment was conducted at Gainesville, Florida in four 27-m long, temperature-gradient greenhouses (TGGs) constructed in the field over an undisturbed Millhopper fine sandy soil. The TGGs were covered with clear polyethylene plastic and measured 4.4 m diameter in circular cross-section. The experiment had two "replicate" TGGs at 350 and two at 700 vpm CO_2. Within each TGG, four temperature sectors (0, 1.5, 3.0, and 4.5 ×C above ambient diurnal temperature cycle) were maintained by unidirectional ventilation relative to solar heating and supplemental heating. CO_2 levels of ambient (nominally 360 vpm) or 700 vpm were maintained by monitoring and injecting of CO_2. Computer control of ventilation, heaters, and CO_2 injection were based on thermocouple inputs and infrared gas analysis of CO_2 levels.

The forages were established on 10 April 1995. Bahiagrass (cv. Pensacola) was established from seed and rhizoma peanut (cv. Florigraze) from rhizomes. Irrigation was provided throughout the season at optimum levels by microjet sprinklers. Weeds were controlled by hand-weeding. Plots were fertilized with K_2O at 10 g m^{-2} prior to planting. A total of 8 g m^{-2} of N was applied in 11 split applications over the season to both species, using a balanced 13-13-13 fertilizer. Individual plot size was 1.8 m by 4.7 m, corresponding to a single temperature sector for a given species in each TGG.

Emerged shoots were counted for the first two months. Light interception was measured with the LICOR line quantum sensor on four dates during 1995. Leaf and canopy carbon exchange rates (CER) were measured at midday on two dates, using the LI-COR LI-6200 Portable Photosynthesis System. Canopy CER was measured using the procedures of Pickering et al. (1993).

Small growth samples of 20 by 35-cm land area were taken in triplicate from each plot on five dates. Samples were taken to 20-cm depth including above and belowground components. Samples were washed and separated into roots, stolon-stems (bahiagrass), rhizomes (Arachis), stems (Arachis), and leaves. Leaf area index, numbers of shoots/tillers, and leaf number per tiller were determined. Plant components were dried at 70 ×C and weighed. Establishment-year herbage yield was estimated with a single harvest on 17 Nov. 1995 (218 d after planting) by cutting with a sickle-bar mower at 4-cm height. Harvested plot size was 1.8 by 4.7-m land area.

RESULTS AND DISCUSSION

Establishment Growth: Early growth was slow. By 18 May, 150-200 bahia plants m^{-2} and 100-200 rhizoma peanut shoots m^{-2} had emerged. Ground cover initially developed slowly, achieving 10-20% for bahiagrass and 20-30% for rhizoma peanut by 1 June. Canopy cover and growth became more rapid during June.

Increasing temperature across cells within the TGGs, and also from outside-ambient to inside the TGGs, accelerated plant establishment in early spring and increased early plant dry matter accumulation, leaf area per plant, as well as leaves per shoot. Doubling CO_2 increased rate of canopy coverage and increased total above- and below-ground biomass accumulation by 14 and 52% for bahiagrass and rhizoma peanut, respectively, when averaged over five sampling dates.

Leaf and Canopy Assimilation: There was no significant temperature treatment effect on leaf or canopy photosynthesis in either species (Table 1). Doubling CO_2 increased leaf photosynthesis by 18% for bahiagrass and 41% for rhizoma peanut when averaged over temperature treatments and two measurement dates. Gross canopy photosynthesis of rhizoma peanut was increased 32% by doubled CO_2; however, canopy photosynthesis of bahiagrass was not significantly increased by doubled CO_2 (increase averaged only 3%).

Herbage Production in Establishment Year: A herbage harvest was made with a sicklebar mower on 17 Nov. 1995 (218 d after establishment). Herbage production of bahiagrass showed a consistent increase with temperature increase (Table 2); however, there was no temperature effect on herbage production of rhizoma peanut. Elevated CO_2 increased harvested herbage of bahiagrass from 321 to 376 g m^{-2} and rhizoma peanut from 318 to 385 g m^{-2}, increases of 17% and 21%, respectively. Herbage yields do not include roots, stolons, rhizomes, and stem stubble. Separate small land-area sampling indicated that doubled CO_2 increased stolon mass of bahiagrass by 13% and rhizome mass (Arachis) by 51%. In this establishment year, both species allocated more total mass to stolon/rhizome than was allocated to "harvestable" herbage mass.

Implications for Climate Change: We conclude that elevating global temperature by 4.5 °C will not adversely impact photosynthesis or growth of these two species under well-watered conditions. Elevated temperature will enhance early season growth and ground cover, possibly increasing total seasonal dry matter production, particularly for the C_4 bahiagrass. Increase in CO_2 will enhance photosynthesis and dry matter accumulation, particularly for the C_3 rhizoma peanut, but the response of C_4 bahiagrass to CO_2 will be less.

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Table 1

Leaf and canopy assimilation of rhizoma peanut and bahiagrass at midday as affected by doubled CO_2 and elevated temperature. Leaf rates were averaged over two replications, two leaves per replication, and two measurement dates, 10 July and 2 Sep. Canopy rates were averaged over two replications and two dates, 13 July and 17 Aug., and are reported as gross assimilation (absolute value of dark respiration added to apparent CER).

Temperature	Rhizoma peanut		Bahiagrass	
Treatment	350 vpm	700 vpm	350 vpm	700 vpm
	mmol CO_2 m^{-2} s^{-1}			
Leaf photosynthesis:				
Ambient (field)	27.3		30.2	
+0.0 ×C	24.0	37.3	35.2	35.7
+1.5 ×C	27.6	37.3	31.9	39.1
+3.0 ×C	26.3	37.5	33.2	36.2
+4.5 ×C	26.7	36.0	31.0	44.1
Canopy gross assimilation:				
Ambient (field)	22.9		26.7	
+0.0 ×C	29.8	41.9	47.1	46.3
+4.5 ×C	33.1	40.9	47.0	51.0

Table 2

Herbage yield, rhizome, stolon, and root mass for rhizoma peanut and bahiagrass on 17 Nov. 1995, as affected by doubled CO_2 and elevated temperature. Dry herbage yield is based on 1.8 by 4.7 m land-area, whereas rhizome, stolon, and root mass are from triplicate samples of 0.20 by 0.35 m land-area. Components should not be summed because sampling methods differ and aboveground aftermath was not included.

Treatment		Herbage yield		Arachis		Bahiagrass	
CO_2/Temp.		Arachis	Bahia	Rhizome	Root	Stolon	Root
vpm	°C	g m^{-2}					
Ambient (field)		179	150	412	30	372	345
350/	+0.0 °C	288	255	508	51	770	432
	+1.5 °C	337	318	501	49	951	371
	+3.0 °C	329	340	424	51	662	310
	+4.5 °C	319	370	366	47	860	275
700/	+0.0 °C	370	350	647	49	870	292
	+1.5 °C	382	379	708	78	890	298
	+3.0 °C	375	372	677	75	922	300
	+4.5 °C	413	403	680	56	985	278