Effect of different temperatures and carbon dioxide levels on biomass accumulation and partitioning in Big Bluestem (*Andropogon gerardii*)

K. Raja Reddy, V.G. Kakani and R. L. King
Mississippi State University, Mississippi State, MS

Rationale and Objective

Greenhouse gases continue to increase in the atmosphere with carbon dioxide concentration ([CO_2]) increasing at an unprecedented rate. The [CO_2] in the atmosphere is expected to double by the end of the century. The increase in [CO_2] since industrialization has resulted in 0.6 °C increase of the Earth's mean temperature. Projections indicate that the Earth's mean temperature would increase anywhere from 1.5 to 11 °C by the turn of the century. These changes in climate would alter the response to [CO_2] and temperature of rangelands that occupy 47% of the Earth's land area and in turn the global carbon budget. Several studies have quantified growth, development, and biomass production and partitioning in response to elevated [CO_2], but not the combined effects of [CO_2] and temperature. The objective of the study was to quantify the effects of both [CO_2] and temperature on growth, biomass production and partitioning in a C4 prairie grass, the Big Bluestem (*Andropogon gerardii*).

Methodologies

Soil-Plant-Atmosphere-Research (SPAR) Facility:
The sunlit controlled-environment plant growth chambers used for this study are known as SPAR units (Plate 1). Each SPAR unit consists of a steel soil bin (1.0 m tall by 2 .0 m long by 0.5 m wide), and a Plexiglas chamber (2.5 m tall by 2.0 m long by 1.5 m wide) to accommodate above ground parts.

Plant Culture:
Seeds of *A. gerardii* cv. 'Bonilla' were sown in 11 rows spaced 20 cm apart in the SPAR units on 18 May 2004. Emergence was observed five days later. At 7 days after emergence (DAE), plants were thinned to 10 per row leaving 110 plants per unit. A computer-controlled timing device supplied half-strength Hoagland's nutrient solution to each chamber through a drip irrigation system.

Treatments:
The [CO_2] was at 360 ± 10 µL L^{-1} and temperature was 30/22 °C till emergence in all SPAR units. At first true leaf stage, the [CO_2] in five SPAR units was elevated to 720 µL L^{-1} while the other five remained at 360 µL L^{-1}. The [CO_2] was monitored every 10 s and integrated over 900-s intervals throughout the day. The five units at a given [CO_2] received five different temperature (day/night) treatments of 20/12, 25/17, 30/22, 35/27, 40/32 °C with mean temperatures of 15, 21, 26, 31 and 36 °C. Air temperature in each SPAR unit was also monitored and adjusted every 10 s throughout the day and night, and maintained within ± 0.5 °C of treatment set points.

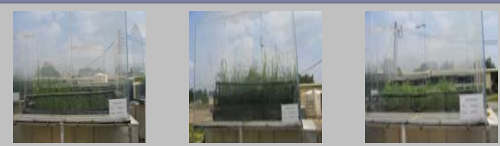
Measurements:
Plant height, tiller number and main stem leaf number were recorded at weekly intervals from 10 to 94 DAS. Nodes with panicles and panicle number per plant were counted at final harvest (125 DAS). At the final harvest, plant components (leaves, stems, panicles and roots) were oven dried at 70 ºC for 3 d before recording the dry weights.

Statistical analysis:
Growth rates of stem elongation, node and tiller addition were calculated. Response functions were fit to identify optimum temperature for growth and biomass and study the effects of [CO_2] treatments.

Results

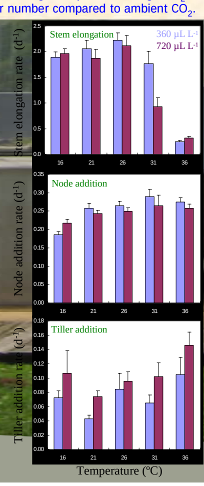
Plate 1. Soil Plant Atmosphere Research Facility

Low temperature (20/12 ºC) | Optimum temperature (30/22 ºC) | High temperature (40/32 ºC)



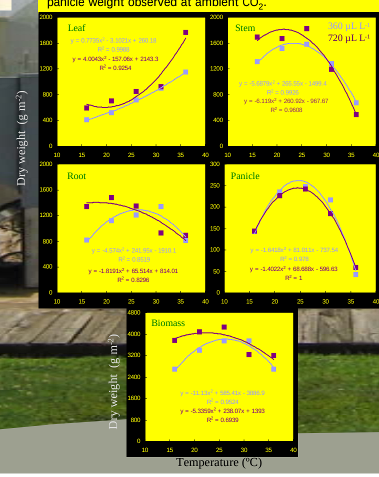
Growth rates

Stem elongation was significantly reduced by temperature >26 ºC, while CO_2 accentuated the effects of high temperatures of 31 and 36 ºC. Node addition or leaf addition was more tolerant to temperature with a decrease in node addition only at 36 ºC and CO_2 did not alter the rates. Addition of tillers was not modified by CO_2 at 26 ºC. But at both low and high temperatures, high CO_2 increased the tiller number compared to ambient CO_2.



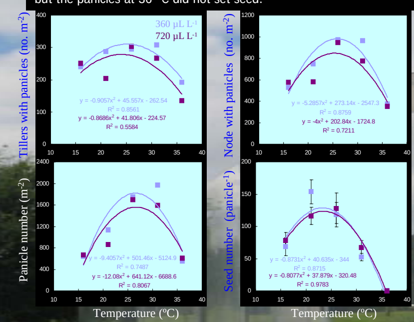
Biomass

Temperatures lower or higher than 26 ºC reduced biomass accumulation. High CO_2 grown plants had higher biomass than ambient CO_2 plants, but the difference narrowed at high temperatures of over 31 ºC. Both stem and root biomass followed similar patters. However, leaf weight increased with increase in temperature and the increase was higher in high CO_2 grown plants. Panicle weight accounted for 3-6% of the total biomass. The high CO_2 treatment did not modify the response to temperature of panicle weight observed at ambient CO_2.



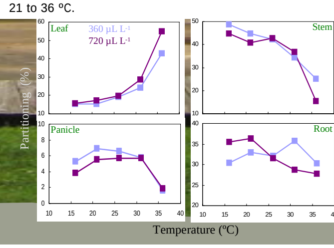
Reproductive parameters

Reproductive parameters responded similarly under both CO_2 treatments. Plants grown under elevated CO_2 had fewer number of panicles compared with those at ambient CO_2 except at 16 and 36 ºC. Seed number per panicle also followed a quadratic trend in response to temperature and was similar across CO_2 treatments. Plants grown at 16 and 36 ºC produced similar number of panicles, but the panicles at 36 ºC did not set seed.



Partitioning

Partitioning of biomass towards leaf and stem followed opposite trends. Increase in temperature increased partitioning to leaves from 15 to 50%, while in stems it reduced from 48 to 20%, averaged over the CO_2 levels. Partitioning to panicles was not much affected from 15 to 31 ºC, but was reduced to 2% at 36 ºC. Partitioning to roots was modified by CO_2 the treatment. At ambient CO_2, partitioning to roots was constant but at high CO_2, a 7% decrease was observed with increase in temperature from 21 to 36 ºC.



Discussion

Mean temperature of 26 °C was found optimal for most of the vegetative and reproductive components studied, except for leaf which showed an increase in weight with increase in temperature. The optimum temperature for root growth was lower (21 °C) at high CO_2 than at ambient CO_2 (26 °C) .

The study demonstrated that high CO_2 would increase the biomass production of the C4 grass, *A. gerardii,* at temperature below optimum (<26 ºC) but has no influence on biomass accumulation at high temperatures. The response of reproductive components to elevated CO_2 was lower in the optimum temperature range and equal at extreme temperature treatments. This suggests that under projected CO_2 conditions, the growing temperature will play a major role in determining the biomass, seed-set and yield of *A. gerardii*.

At temperatures >26 ºC and under both CO_2 treatments, panicle weight was reduced by 20-80% and seed number per panicle was also reduced by 50-100%, suggesting that vegetative propagation might have to resorted to for multiplication of *A. gerardii*.

The allocation of biomass under elevated CO_2 and high temperature conditions is greater to leaves with a decrease in allocation to culms, roots and seed. This suggests that less carbon will be sequestered into plant parts that can used for long term storage.

Conclusions

- ✓ Temperature had a greater effect on growth than CO_2 enrichment.
- ✓ Plant biomass and components are reduced at temperatures beyond the optimum except for leaf biomass.
- ✓ Sequestration of carbon into organs for long term storage will be hampered in future climates.
- ✓ The C4 species, *A. gerardii,* may not be a potential candidate for carbon sequestration in climates with high temperature.

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Background is the SPAR Facility