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Progress Report

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Rangeland - Plant Response to Elevated CO_2

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Summary

Effects of carbon dioxide enrichment on a tallgrass ecosystem were monitored during the 1990 growing season. The chambers, CO_2 delivery system, and data acquisition and control system were in place and operational by 4 April 1990. CO_2 fumigation and data acquisition began on that date. Nitrogen fertilizer as ammonium nitrate was applied at a rate of 45 kg ha $^{-1}$ on 1 April to the N-fertilized plots. The chambers were 4.5 m in diameter and 4 m in height to allow for destructive sampling for biomass accumulation, leaf area determination, and for grazing esophageally-fistulated sheep. The experimental site was located in pristine Tallgrass Prairie north of/and adjacent to the Kansas State University campus . Vegetation on the site was a mixture of C3 and C4 species and was dominated by big bluestem (Andropogon gerardii vitman) and indiangrass [Sorghastrum nutans (L.) Nash]. Subdominants included Kentucky bluegrass (Poa pratensis L.), sideoats grama [Bouteloua curtipendula (Michx.) Torr.], and tall dropseed [Sporobolus asper var. asper (Michx.) Kunth]. Members of the sedge family made up 5-10% of the composition. Principal forbs included western ragweed (Ambrosia psilostachya DC.), Louisiana sagewort (Artemesia ludoviciana Nutt.), and manyflower scurfpea [Psoralea tenuiflora var. floribunda (Nutt.) Rydb.]. Average peak biomass occurs in early August at 425 g m^{-2} of which 35 g m^{-2} is from forbs. The area was ideal for meeting the experimental objectives listed below, in that the mixture of C3 and C4 plants would allow for assessment of competitive relationships among numerous species of both carbon fixation pathways.

Objectives

- To characterize the effects of double ambient CO_2 enrichment and nitrogen fertilization on changes in diet selection and diet quality for ruminants.
- To monitor plant population dynamics under ambient and CO_2 -enriched atmospheres with and without nitrogen fertilization.
- To measure biomass accumulation and leaf area during the growing season under ambient and CO_2 enriched atmospheres with and without nitrogen fertilization.
- To derive growth dynamics parameters for Andropogon gerardii under ambient and CO_2-enriched environments with and without nitrogen fertilization.
- To determine relative root biomass accumulation in ingrowth bags under ambient and CO_2 -enriched environments with and without nitrogen addition.
- To determine surface litter dynamics under ambient and CO_2 -enriched environments with and without nitrogen addition.

In this report we detail ambient and chamber environment, biomass and leaf area response to CO_2 enrichment, growth dynamics analysis, root ingrowth bag biomass, and forage quality of samples collected in 1989 by clipping. Listed below are the important outcomes for 1990.

1. Large, open-top chambers constructed of structural aluminum and covered with polyethylene film were used . A truncated, cone-type baffle was added to the top of the chambers to decrease CO_2 requirement and to stabilize CO_2 concentration in the enriched chambers. Similar to 1989, these chambers reduced photosynthetically-active radiation (PAR) by 11% over the course of the experiment, but did not increase air temperature at maximum plant height (30 cm) or soil temperature (-10 cm) when compared to unchambered areas. Air temperature at 100 cm was slightly increased on the hottest days, and air temperature at 300 cm was much higher in chambered plots than that of unchambered ones. Chamber air was changed three times per minute. Soil moisture levels were higher in chambers during most of the growing season. Dewpoint was higher in chambered than in unchambered plots.

2. CO_2 concentration in the enriched chambers was maintained at double that of the ambient condition during the entire 24-hr day. During nighttime hours, CO_2 levels in the enriched chambers peaked at 750-760 ppm, and ambient CO_2 levels at night were 370-380 ppm. During the day with maximum photosynthesis, CO_2 levels in the enriched chambers were 680-690 ppm, and ambient levels were 340-345 ppm. Wind velocity and air temperature both affected the amount of CO_2 required to maintain target CO_2 level.

3. In 1990 we added nitrogen fertilization to the experiment. The added treatments were CO_2 -enriched +N, Chamber Ambient CO_2 + N, and Ambient CO_2 + N which were replicated twice.

4. No-Nitrogen Plots - Total biomass on no-nitrogen plots, determined biweekly, was generally higher in chambered plots, whether CO_2 -enriched or not, than in unchambered plots. When compared to 1989 there appeared to be no CO_2 enrichment effect. By comparing data from 1989 and 1990, we were able to conclude that the chamber effect and CO_2 -enrichment effect were confounded. It appears that the major response to CO_2 in the Tallgrass Prairie ecosystem is mediate In 1989, conditions were so dry that the chamber effect was minimal, as

evidenced by a lack of difference shown in dewpoint temperature between chambered and unchambered plots. In 1990, dewpoint temperatures were higher in chambered plots than in unchambered ones. There was no difference in Kentucky bluegrass (C3) biomass accumulation among the chamber-enriched, chamber ambient, and unchambered plots. That was likely due to the nitrogen limitation on growth of C3 species in this ecosystem. C4 species also quickly overtop the shorter C3 plants providing further reduction in their growth potential. Forb biomass and total biomass accumulation did not differ among the CO_2 treatments.

5. N-Fertilized Plots - There was a greater big bluestem biomass in CO_2 -enriched plots than in chamber-ambient and ambient CO_2 plots. That result may support the conclusion that response to CO_2 enrichment can be limited by nitrogen availability. Kentucky bluegrass, forb, and total biomass did not differ among treatments

6. Leaf area index (LAI) responded to CO_2 enrichment and chamber effect similarly to biomass on both no-N and N-fertilized plots.

7. As in 1989, half of each plot was grazed by esophageally-fistulated sheep. Sheep were grazed for a 15-minute period every two weeks and samples of their masticate collected. Acid detergent fiber, acid detergent indigestible nitrogen, series in vitro dry matter digestibility, and nitrogen content will be determined on freeze-dried samples.

8. Forage quality was measured on the biomass samples clipped at different dates in 1989 . Nitrogen concentration and acid detergent fiber (ADF) were determined. Nitrogen levels in big bluestem, warm-season perennial grasses, and Kentucky bluegrass were lower in CO_2-enriched plots than in chamber-ambient and ambient CO_2 plots. ADF concentration was higher with CO_2 enrichment than under chamber-ambient and ambient CO_2. The impact of the reduced N and increased ADF is a reduced forage quality which would reduce intake and lower animal gains. Nitrogen concentration in big bluestem was similar for chamber-enriched and chamber-ambient plots in 1990 but was lower than taht of the unchambered-ambient plots. Kentucky bluegrass had lower N concentration in the CO_2 -enriched plots than in chamber-ambient and ambient CO_2 plots. On plots with N fertilization, big bluestem had lower N concentration on CO_2 -enriched plots than the chamber-ambient or ambient CO_2 plots, and the

ambient CO_2 plots had a lower N concentration than chamber-ambient ones. As with unfertilized plots, Kentucky bluegrass on fertilized plots had lower N concentration in the CO_2 -enriched plots than in chamber-ambient and ambient CO_2 plots.

9. Root ingrowth bags indicated that root production under CO_2 -enriched plots without added nitrogen was 1.96 times that of chamber ambient and ambient CO_2 plots.

10. Big bluestem, indiangrass, and Kentucky bluegrass standing dead from CO_2 -enriched, chamber ambient CO_2 , and ambient CO_2 plots with and without added N was collected in early November, 1990 and placed in litter bags. In mid-November the bags were placed in contact with mineral soil and five bags per treatment will be retrieved after 4, 6, 9, 12, and 24 months. Nitrogen, ADF, and lignin will be determined on the retrieved samples.

11. Precipitation in 1990 was slightly below normal. Temperatures averaged slightly above normal for the functional growing season.