IMPACT OF ELEVATED CO_2 AND TEMPERATURE ON SOIL CARBON SEQUESTRATION POTENTIAL OF TWO CONTRASTING SUBTROPICAL GRASSLAND SPECIES, A C_4 GRASS AND A C_3 LEGUME

L.H. Allen, Jr[1], S.L. Albrecht[2], K.J. Boote[3], J.M.G. Thomas[3], and K.W. Skirvin[2]

[1]*Crop Genetics & Environmental Research, USDA-ARS, 1600-1700 SW 23 Drive, Gainesville, FL 32608; lhajr@mail.ifas.ufl.edu*

[2]*Columbia Plateau Conservation Research Center, USDA-ARS, P.O. Box 370, Pendleton, OR 97801-0370; stephan albrecht@oregonstate.edu;.skirvin@oregonstate.edu*

[3]*Department of Agronomy, University of Florida, 304 Newell Hall, Gainesville, FL 32611-0500; kjb@mail.ifas.ufl.edu; jmth@grove.ufl.edu*

ABSTRACT
Carbon sequestration in soils might offset part of the increase of CO_2 in the atmosphere. Two contrasting subtropical grassland species, bahiagrass (BG), *Paspalum notatum* Flügge, and rhizoma perennial peanut (PP), *Arachis glabrata* Benth., a legume, were grown at Gainesville, Florida, USA, in field soil plots in four temperature zones (baseline-ambient, +1.5, +3.0, and +4.5 °C) in four temperature-gradient greenhouses, two each at 360 and 700 ppm CO_2. The soil had been in continuous cultivation for more than 20 years before plant establishment. Samples from the top 20 cm of each plot were collected before plant establishment and six years later, after the study ended. Soil organic carbon (SOC) increases across the six years were greater for BG than PP, 1.396 and 0.746 g/kg, respectively. Belowground biomass was also greater for BG than PP. Mean SOC gains in BG plots at 700 and 360 ppm CO_2 were 1.450 and 1.343 g/kg, respectively (no CO_2 effect). Mean SOC increases in PP plots at 700 and 360 ppm CO_2 were 0.949 g/kg and 0.544 g/kg, respectively (significant CO_2 effect). Overall, SOC increased only for the first temperature increment, and thereafter declined. Soil organic nitrogen (SON) accumulation patterns were similar to SOC increases. Mean annual SOC accumulation was 475 kg/ha per year, comparable with other studies. We conclude that carbon can be accumulated in soils converted to grassland species in humid, subtropical environments. The SOC accumulation will be greatest for species that have greater belowground biomass accumulation.

INTRODUCTION
Sequestration of carbon in the soil can decrease the amount of CO_2 in the atmosphere and potentially mitigate the impact of global warming by rising greenhouse effect gases [*Izaurralde et al*., 2001]. Much work has been done on carbon sequestration by natural grasslands [*Schuman et al*., 2002; *Sperow et al*., 2003; *Pendall et al*., 2004], but less work has been done on managed grasslands, especially in the humid Southeastern USA [*Franzluebbers et al*., 2000). The objectives were to determine the amounts of SOC and SON accumulation across time after establishment of two forage species, BG and rhizoma PP, in a Florida sandy soil previously under cultivation for more than 20 years and to determine the impact of both elevated CO_2 concentration and temperature on accumulation of SOC and SON by these two species in a humid, subtropical environment.

MATERIALS AND METHODS
On 10 April 1995, 'Pensacola' BG seeds were sown and 'Florigraze' PP rhizomes were incorporated into the soil in four computer-controlled temperature-gradient greenhouses (TGG). Each TGG was placed over natural field soil profiles (Millhopper fine sand, a loamy, siliceous, hyperthermic, Grossarenic Paleudult). Four experimental zones were maintained at baseline-temperature, +1.5, +3.0, and +4.5ºC, respectively by controlled injections of heated air and controlled ventilation. Two TGGs were maintained at 360 (ambient) and two at 700 ppm CO_2. Fertilizer was applied according to plans and plots were irrigated to exceed evapotranspiration slightly. Herbage was harvested three to four times during each year from 1995 through 2000. Details of treatment conditions, fertilizer applications, irrigation, and herbage yields were reported earlier [*Newman et al., 2001*]. Four replicated soil samples from the top 20 cm of each plot were collected in February 1995 before forage establishment and in December 2000 when the study ended. Soil samples were analyzed for total C and N in a Thermo-Finnigan FlashEA 1112 CNS analyzer.

RESULTS AND DISCUSSION

Overall Effects. Mean SOC increased by 1.081 g kg^{-1}, from 4.185 to 5.266 g kg^{-1} ($P < 0.01$), an increase of 26%. Mean SON increased by 0.095 g kg^{-1}, from 0.277 to 0.372 g kg^{-1}, an increase of 34% ($P < 0.01$). Thus, forages promoted SOC accumulation in subtropical environments on previously cultivated land.

Species Effects. Mean SOC increased by 1.396 g kg^{-1} for BG and 0.746 g kg^{-1} for PP, a BG/PP ratio of 1.87 ($P < 0.01$). Mean SON increased by 0.1118 g kg^{-1} for BG and 0.0765 g kg^{-1} for PP, a BG/PP ratio of 1.46 ($P < 0.01$). Thus BG accumulated more SOC than PP, although PP herbage yields were higher [*Newman et al*., 2001]. In 1997, mean belowground biomass of BG and PP was 2.3 and 1.3 kg m^{-2}, respectively [*Boote et al*., 1999]. The belowground biomass ratio (1.78) was consistent with the BG/PP accumulated SOC ratio (1.87). Thus, SOC and SON accumulations depended on the forage species.

CO_2 Effects. Mean SOC increased by 0.943 g kg^{-1} for 360 ppm and 1.199 g kg^{-1} for 700 ppm CO_2, a ratio of 1.27 ($P < 0.01$). Likewise, mean SON increased by 0.0886 g kg^{-1} for 360 ppm and 0.0997 g kg^{-1} for 700 ppm, a ratio of 1.13 ($P = 0.08$). Thus, accumulation of SOC was enhanced by elevated CO_2.

Temperature Effects. Mean SOC increased by 1.18, 1.21, 0.97, and 0.92 g kg^{-1} at the four increasing temperature treatments ($P = 0.03$). Likewise, mean SON increased by 0.104, 0.106, 0.087, and 0.079 g kg^{-1} ($P < 0.01$). A slight increase above Gainesville, Florida, ambient temperatures did not change SOC and SON accumulation, but further increases in temperature would lead to lesser accumulation. This trend occurred despite increased herbage yields across increasing temperature treatments [*Boote et al., 1999; Newman et al., 2001*]. SOC and SON accumulations were diminished for 3°C or more above current Gainesville ambient temperatures.

Species x CO_2 Interactions. Mean SOC increased 0.544 g kg^{-1} for PP at 360 ppm, 0.949 g kg^{-1} for PP at 700 ppm, 1.343 g kg^{-1} for BG at 360 ppm, and 1.450 g kg^{-1} for BG at 700 ppm. Thus, the SOC ratio of PP700/PP360 = 1.74 and the SOC ratio of BG700/BG360 = 1.08. Mean SON increased 0.0655 g kg^{-1} for PP at 360 ppm, 0.0875 g kg^{-1} for PP at 700 ppm, 0.1117 g kg^{-1} for BG at 360 ppm, and 0.1118 g kg^{-1} for BG at 700 ppm. Thus, the SON ratio of PP700/PP360 = 1.34 and the SON ratio of BG700/BG360 = 1.00. Elevated CO_2 caused a large increase of SOC accumulation in PP but a small increase in BG. Elevated CO_2 caused a noticeable increase of SON accumulation in PP but no increase in BG. Species x CO_2 interaction was weak for both SOC and SON ($P = 0.08$).

REFERENCES

Boote, K. J., L. E. Sollenberger, L. H. Allen, and T. R. Sinclair (1999), Carbon balance and growth adaptation of contrasting C3 and C4 perennial forage species in increased CO_2 and temperature, *Report # 73, Southeast Regional Center, National Institute for Global Environmental Change*, University of Alabama, Tuscaloosa, AL 35487-0207.

Franzluebbers, A. J., J. A. Stuedemann, H. H. Schomberg, and S. R. Wilkinson (2000), Soil organic C and N pools under long-term pasture management in the Southern Piedmont USA, *Soil Biol. & Biochem. 32*, 469-478.

Izaurralde, R. C., N. J. Rosenberg, and R. Lal (2001), Mitigation of climate change by soil carbon sequestration: Issues of science, monitoring, and degraded lands, *Advances in Agronomy 75*, 1-75.

Newman, Y. C., L. E. Sollenberger, K. J. Boote, L. H. Allen, and R. C. Littell (2001), Carbon dioxide and temperature effects on forage dry matter production, *Crop Sci. 41*, 399-406.

Pendall, E., A. R. Mosier, and J. A. Morgan (2004), Rhizodeposition stimulated by elevated CO_2 in a semiarid grassland, *New Phytologist 162*, 447-458.

Schuman, G. E., H. H. Janzen, and J. E. Herrick (2002), Soil carbon dynamics and potential carbon sequestration by rangelands, *Environ. Pollut. 116*, 391-396.

Sperow, M., M. Eve, and K Paustian (2003), Potential soil C sequestration on US agricultural soils, *Climate Change 57*, 319-339.