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Infrequently burned prairies dominated by *Andropogon gerardii* and their role in carbon sequestration

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Abstract

Global climate change has been widely attributed to the accumulation of CO_2 in the atmosphere. This global warming is brought on by excess atmospheric carbon dioxide produced by the burning of fossil fuels. However, the burning of biomass does not contribute a net gain in atmospheric CO_2 because this carbon is part of the active carbon cycle, whereas the carbon in fossil fuel emissions originates from the inactive carbon cycle, and is therefore not returned to its fossil fuel state as quickly as it is released. Soil organic matter (SOM) may hold up to four times the carbon of living biomass, giving land with high levels of SOM the potential to act as carbon sinks to counteract global warming. In our study, we sought to determine which prairie grass species accumulated the greatest amount of biomass, which is directly related to the organism's ability to accumulate carbon. We also studied the effects of fire on SOM levels. We found that there is no significant difference in SOM between annually burned and unburned prairie plots. We also found that certain native warm-season (C_4) grasses, particularly A. gerardii, produce significantly larger amounts of both above and belowground biomass than do cool-season (C_3) species. In addition, we have determined that an infrequently burned prairie dominated by A. gerardii, as most native tallgrass prairies are, will act as an effective carbon sink.

Introduction

In recent decades much discussion in both scientific and lay forums has focused on global warming, the idea that temperatures worldwide are increasing and causing climate change. By this hypothesis, these climatic changes are caused primarily by the buildup of the greenhouse gas carbon dioxide (CO_2) in the atmosphere (Magdoff 1992, PNNL 1998). The amount of CO_2 present in the atmosphere inevitably involves the carbon cycle. According to Magdoff (1992), in the active part of the carbon cycle, plants take in CO_2 from the atmosphere through photosynthesis, and incorporate the carbon into their organic matter. This process is described by the equation:

$$CO_2 + H_2O \Leftrightarrow (CH_2O) + O_2,$$

where CH_2O is the base formula for biological materials (Andreae, 1991). CO_2 is released in the reverse reaction as plants and animals respire. CO_2 is also released by burning (Magdoff 1992, Lovejoy 1991). While the CO_2 released in the incineration of plants is part of the active carbon cycle and therefore does not increase total atmospheric CO_2, the CO_2 created by the combustion of fossil fuels originates in the inactive carbon cycle, and thus upsets the balance of atmospheric CO_2 (Magdoff 1992).

The concern over increasing atmospheric CO_2 levels in recent years has fostered the interest in the concept of the carbon sink. According to this idea, land is managed so that the excess carbon in the atmosphere is confined, or sequestered, in the soil as undecomposed organic matter. The Department of Energy's Pacific Northwest National Laboratory (1998) concluded that a change in land management techniques could remove 40 to 80 billion metric tons of carbon from the atmosphere over the course of the next 50 to 100 years.

We investigated what circumstances in a prairie would create the optimal amount of carbon sequestration. To do so, we examined the biomass of several prairie grass species, which, according to Andreae (1991), can be directly linked to the amount of carbon accumulated. Certain management techniques, like burning, may favor particular species of grasses. Fire may then have an effect on SOM. We therefore studied the effect of annual burning on soil organic levels. This aspect of the experiment was conducted at Grinnell College's Conard Experimental Research Area (CERA), in ten plots left unburned and ten plots burned every spring since 1997. We predicted that there would be differences between the five species and that *Andropogon gerardii* would accumulate the largest total biomass. We also expected to find similar amounts of SOM in annually burned and unburned prairies (Seastedt and Knapp 1991).

Methods

Determining Biomass of Prairie Species

We chose our species based on their readiness to germinate and because we desired a blend of cool-season (*Bromus kalmii*) and warm-season grasses (*Panicum virgatum*, *Andropogon scoparius*, *Sorgastrum nutans* and *Andropogon gerardii*). With the exception of *A. gerardii*, whose seeds were already available at the college, we obtained all seeds from Prairie Moon Nursery in Winona, Minnesota.

We seeded 15 to 25 seeds of each of our five species in twenty 5.6 cm pots. We thinned as germination progressed so that each pot contained only three individuals. We randomly distributed the pots on trays fitted with four 34W florescent growth lights in a greenhouse. We checked the plants' progress daily and watered as necessary, applying equal amounts of deionized water to each pot. The lights were kept at the same height for all trays, set at a short distance above the tallest plant of any tray.

We collected data after ten days. For the first three weeks of collection, we removed plants from three randomly selected pots of each species. In the fourth week, however, we processed the remaining 11 pots of each species. We divided the plants into aboveground and belowground portions, removing as much soil as possible from the roots. To remove moisture, we placed the seedlings in a drying oven at 65º C for 24 hours. We then determined the mass of the aboveground and belowground portions of each pot.

We used ANOVA to compare species, weeks, and the interaction between species and week for above and belowground biomass. The post hoc Tukey test made pairwise comparisons of the biomass of each species to all others.

Determining Organic Matter Content of Burned and Unburned Prairies

We took two random soil samples from each of the 20 plots at the Burn/No Burn experiment in CERA on November 2nd, 2000. Subsequently, we divided each

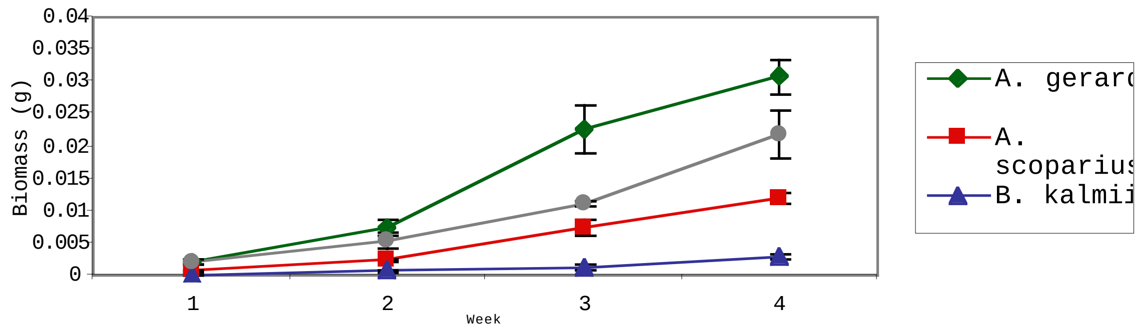

Figure 1: Mean (+/- SE) aboveground biomass for A. ger scoparius, B. kalmii, P. virgatum Data collected from 20 pots species over 4 weeks.

24 cm sample was in half in order to assess SOM content at different soils depths.

We processed the soil samples in accordance with the "Soil Organic Matter" handout (Brown and Caruso, 2000). We used the Loss on Ignition (LOI) method, which involves placing soil filled crucibles in a muffle furnace to incinerate organic matter, so that we could determine SOM content. We used a t-test to compare LOI values between treatments.

Results

Aboveground Biomass

The ANOVA revealed significant differences biomass from week to week (F = 41.10, P = 0.000), from species to species (F = 10.74, P = 0.000), and in the interaction between the week and the species (F = 3.12, P = 0.001). We discovered significant differences between the aboveground biomass accumulation of the following pairs of species: *B. kalmii* to *S. nutans* (T = 3.688, P = 0. 0037) and *P. virgatum* (T = 3.791, P = 0.0026), and *A. gerardii* to *B. kalmii* (T = -6.193, P = 0.0000) and *A. scoparius* (T = -4.311, P = 0.0004) (fig. 1). All other comparisons were not significant. The most dramatic difference in aboveground biomass occurred between *A. gerardii* and *B. kalmii*. At the fourth and final data collection, *A. gerardii* had 1240% of the biomass of *B. kalmii*.

Belowground Biomass

There were significant differences in belowground biomass from week to week (F = 13.57, P =0.000), from species to species (F = 5.23, P = 0.001), and in the interaction between the week and the species (F = 1.90, P = 0.047). Significant differences also occurred in the belowground biomass between *A. gerardii* and both *A. scoparius* (T = -3.783, P = 0.0027) and *B. kalmii* (T = -4.065, P = 0.0010) (fig. 2). Although the differences between *B. kalmii* and both *S. nutans* and *P. virgatum* were not significant at first, they were significant during the last week (T = 3. 091, P = 0.0258 and T = 3.601, P = 0.0063, respectively). The most notable difference in the belowground biomass occurred again between *A. gerardii* and *B. kalmii*. *A. gerardii* established approximately 900% more biomass by the last data collection.

Soil Organic Matter

As expected, we discovered a significant difference between the top 12 cm of the soil and the bottom 12 in both burned and unburned plots (T = 2.149, P = 0.038, and T = 6.763, P = 0.000, respectively) (fig. 3). However, we found no significant difference between the top 12 cm of the burned soil and the top 12 cm unburned counterpart (T = -0.45, P = 0.654). The same trend applied to the bottom 12 cm of the soil samples (T = 0.315, P = 0.755).

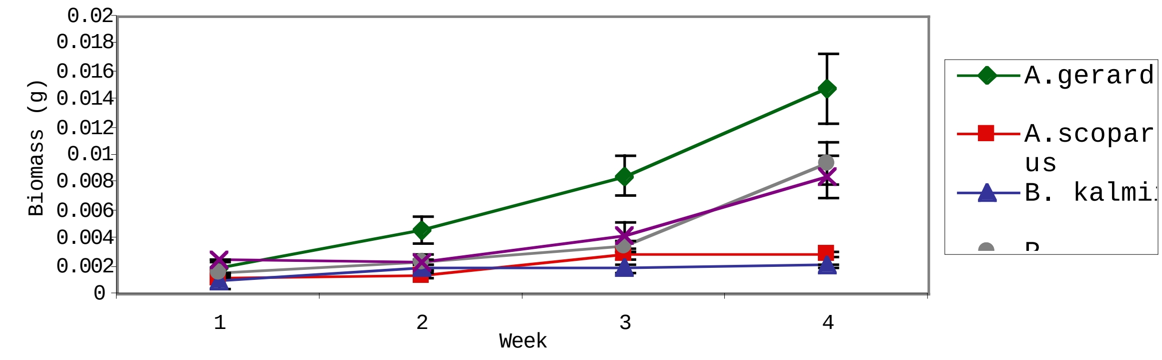

Figure 2: Mean (+/-SE) belowground biomass for A. gerardii, A. scopar
virgatum, S. nutansData collected from 20 pots of each species ove

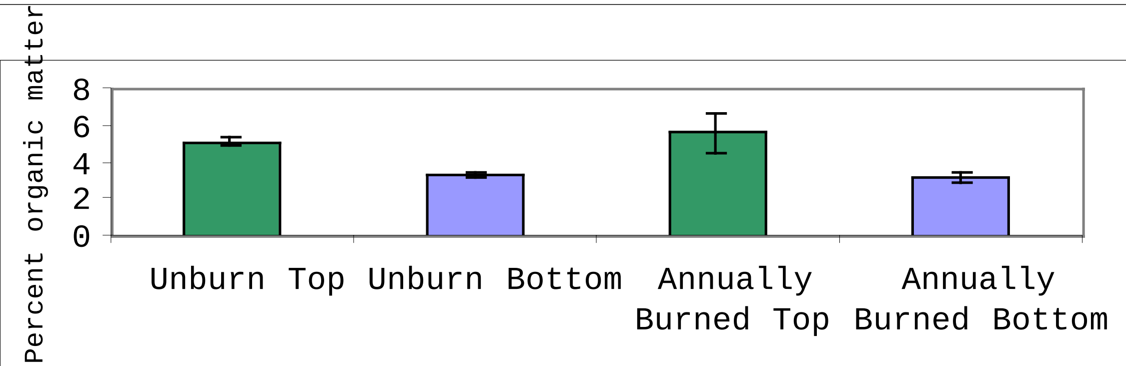

Figure 3: Mean (+/-SE) percent organic matter in soil of burned and unb
samples were collected at CERA on November 2, 2000 from 10 annually bu
unburned plots. Two soil samples were collected from each pl

Discussion

We attribute the significantly smaller growth of *B. kalmii* when compared to *A. gerardii*, *P. virgatum* and *S. nutans* to their preferred growing conditions. As a cool-season (C_3) grass, *B. kalmii* may be less suited to the higher temperatures favored by the C_4 grasses. We reason that there is no significant difference between the growth of *B. kalmii* and *A. scoparius* because *A. scoparius*, better suited to more arid climates is naturally a much smaller plant then the other warm-season (C_4) grasses (Robertson 1999).

The lack of significant differences in the SOM levels between the annually burned and unburned prairies is consistent with the results of other studies. A study by Seastedt and Knapp (1991) concluded that prairie productivity is significantly higher when burning is infrequent, while productivity is similar when burning occurs annually or is nonexistent. According to this study, infrequent burning creates a high nitrogen and water demand that leads to more robust root formation, which is beneficial to SOM content.

The results of our study indicate that prairie SOM is not affected by annual burning. Prairies have the largest amount SOM when they are burned at moderate intervals (Seastedt and Knapp 1991). Since larger grasses tend to create more SOM, the large C_4 grasses will benefit SOM. While species such as *A. scoparius* perform the best in arid conditions (Robertson 1999), the climate of Iowa is generally more hospitable to *S. nutans*, *P. virgatum*, and especially *A. gerardii.* This result is not a surprise, as *A. gerardii* has historically been the dominant species on the tallgrass prairie. The tallgrass prairie is therefore responsible for a huge amount of SOM (Seastedt and Knapp 1991).

Buyanovsky *et al.* (1987) found that up to 50% of the SOM content was lost with the conversion of prairies to agricultural land. Although significant amounts of SOM are no longer being lost, the levels are not increasing. Proper management of prairies and croplands would potentially restore much of the lost SOM to the soil. The restoration of SOM would turn the prairie into an effective carbon sink, therefore slowing global warming.

Future research might study the performance of the grasses in the field rather than in the artificial environment of the greenhouse. Experimenters should gather the seeds for the field study locally to take advantage of adaptations to local conditions. They should also include a wider mix of species and study them over a much longer time frame. We also think that future experiments should involve mixtures of both grasses and forbs to better simulate natural conditions. An experiment incorporating these designs at CERA would consist of numerous replicates of differently seeded plots; each subdivided into annually burned, unburned and infrequently burned areas.

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