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ScienceDirect

Procedia Environmental Sciences 29 (2015) 158 – 159

Procedia Environmental Sciences

Agriculture and Climate Change - Adapting Crops to Increased Uncertainty (AGRI 2015)

Responses of a grassland ecosystem to 17 years of free-air CO_2 enrichment

L. C. Andresen[a]*, N. Yuan[b], J. Luterbacher[b], G. Moser[a], C Müller[a], L. Grünhage[a], C. Kammann[a,c]

a JLU-Giessen, Department of Plant Ecology, b JLU-Giessen, Institut für Geographie Bereich Klimatologie, Klimadynamik und Klimawandel, c Hochschule GEISENHEIM University

Abstract

Grasslands comprise 70% of all agricultural land worldwide, and provide fodder for life-stock and besides being habitats for flora and wildlife, they contain large carbon and nitrogen stocks. Elevated CO_2 concentrations usually increase plant growth in the short-term, particularly in well-fertilized and irrigated crops. Furthermore, plant tissue nutrient concentrations decrease and the subsequent increase in the CN ratio is assumed to be a symptom of a "progressive nitrogen limitation" (PNL), which is still under debate since long-term FACE experiments are scarce.

The Giessen FACE experiment started in a N-limited, species-rich grassland ecosystem near Giessen, Germany in 1998. The CO_2 concentration was enriched (eCO_2) +20% above ambient (aCO_2) year-round during daylight hours. Biomass was harvested twice: in spring and late summer, sorted into the functional groups grasses, forbs and legumes, and the plant material was analyzed (Inductively Coupled Plasma Mass Spectrometer ICP–MS and MS) for N and other nutrients.

* Corresponding author. Tel.: +49 641 99 35320; fax: +49 641 99 35309

E-mail address: louise.andresen@bot2.bio.uni-giessen.de

Peer-review under responsibility of the organizing committee of the Agriculture and Climate Change - Adapting Crops to Increased Uncertainty (AGRI 2015)
doi:10.1016/j.proenv.2015.07.238

Biomass of grasses was increased by elevated CO_2 during the whole 17 years (1998-2014) indicating that dominant grasses react quickly to elevated CO_2, while biomass of forbs was first smaller under elevated CO_2 until 2007, and then became larger at eCO_2 from 2008 to 2014. Elemental concentrations (Ca, Mg, S, N) were decreased by elevated CO_2 in grasses, forbs and legumes. However, K and Zn concentrations in forbs and Mn in legumes increased under elevated CO_2. During the first 11 years (1998-2008), the removed net N pool with the harvested biomass, was identical under elevated and ambient CO_2 conditions, revealing increased N use efficiency under elevated CO_2. Weather conditions (extreme summers) should also be taken into account to better understand the mechanisms of long-term biomass response.

Our preliminary conclusions are (1) the increasing yield response over time does not support PNL in N-limited grassland, (2) co-existing functional plant groups have different response patterns.

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Keywords: grasses, forbs, nitrogen, essential nutrients, FACE