Title: Bridging the Divide: Linking Genomics to Ecosystem Responses to Climate Change
Project ID: 0010138
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Progress Report 2013

Results to date:
We have continued to make progress in addressing the objectives of the funded project: 1) to assess the effects of altered precipitation patterns (i.e., increased variability in growing season precipitation) on genetic diversity of the dominant C_4 grass species, *Andropogon gerardii*, and 2) to experimentally assess the impacts of extreme climatic events (heat wave, drought) on responses of the dominant C_4 grasses, *A. gerardii* and *Sorghastrum nutans*, and the consequences of these response for community and ecosystem structure and function. Below is a summary to date of progress made by our research program since our last report in addressing these objectives. **Note:** *In order to provide a more comprehensive report and permit assessment of the entire project, we have added progress made in year 3 to our list of accomplishments in years 1 & 2.*

Objective 1
After ten years of altered precipitation, we found the number of genotypes of *A. gerardii* was significantly reduced compared to the ambient precipitation treatments (Avolio *et al., in press*). Although genotype number was reduced, the remaining genotypes were *less* related to one another indicating that the altered precipitation treatment was selecting for increasingly dissimilar genomes (based on mean pairwise Dice distance among individuals). For the four key genotypes that displayed differential abundances depending on the precipitation treatment (G1, G4, and G11 in the altered plots and G2 in the ambient plots), we identified phenotypic differences in the field that could account for ecological sorting (Avolio & Smith, *in prep*). The three altered rainfall genotypes also have very different phenotypic traits in the greenhouse in response to different soil moisture availabilities (). Two of the genotypes that increased in abundance in the altered precipitation plots had greater allocation to root biomass (G4 and G11), while G1 allocated more biomass aboveground (Avolio & Smith, *in press*). These phenotypic differences among genotypes suggests that changes in genotypic structure between the altered and the ambient treatments has likely occurred via niche differentiation, driven by changes in soil moisture dynamics (reduced mean, increased variability and changes in the depth distribution of soil moisture) under a more variable precipitation regime, rather than reduced population numbers (*A. gerardii* tiller densities did not differ between altered and ambient treatments; $p = 0.505$) or *a priori* differences in genotype richness (Avolio *et al. in press*). This ecological sorting of genotypes, which accounts for 40% of all sampled individuals in the altered plots, is an important legacy of the press chronic climate changes in the RaMPs experiment.

Objective 2
In May 2010, we established the *Climate Extremes Experiment* at the Konza Prairie Biological Station. For the experiment, a gradient of temperatures, ranging from ambient to extreme, were imposed in 2010 and 2011 as a mid-season heat wave under well-watered or severe drought conditions (Figs. 3 and 4; Smith 2011). We have collected data on physiological and growth responses of the two grasses, as well as leaf tissue for genomic and ABA analysis. In addition, we permanently tagged 1200 individuals and collected leaf tissue for genotyping. This study is allowing us for the first time to examine species-specific thresholds of responses to climate extremes and assess how these phenotypic responses may impact selection of particular genotypes, with the ultimate goal of linking alterations in individual performance and genetic diversity to ecosystem structure and functioning.

We found evidence for differential sensitivities of the co-dominant species to the severe drought and heat wave treatments and their interactions.   As predicted, *S. nutans* was more sensitive to drought than *A. gerardii* based on reductions in both photosynthesis (-88% *S. nutans* and -60% *A. gerardii*) and productivity (- 54% *S. nutans*, non-significant reduction for *A. gerardii*). When we examined the effects of heat on photosynthesis, we found a strong interaction with precipitation. In both years, the only response to heat was within the wetter, ambient treatments, and not the drought treatments. While *A. gerardii* appeared more physiologically sensitive to the heat treatments than *S. nutans*, there were no significant effects ($p > 0.05$) on productivity for either species.

During the 2012 recovery year, all plots received ambient rainfall (supplemented with irrigation to maintain long-term monthly means), and ambient temperature. We found that despite the extreme production response observed during the drought that was driven by a loss in function of both *A. gerardii* and the dominant forb species, *Solidago Canadensis*, that productivity recovered completely one year post-drought. This rapid recovery was driven by rapid demographic responses of A. gerardii, which compensated for continued loss of function of S. Canadensis. We are currently analyzing how soil CO2 responded post-drought.

Papers and other products delivered:

Avolio, M.L. and M.D. Smith. 2013. Intra-specific responses of a dominant C_4 grass to altered precipitation patterns. *Plant ecology*, in press.

Avolio, M. and M.D. Smith. 2013. Correlations between genetic and species diversity: effects of resource quantity and heterogeneity. *Journal of Vegetation Science*, in press.

Avolio, M.L., C.C. Chang, J.J. Weis, and M.D. Smith. The effect of genotype richness and genomic dissimilarity of *Andropogon gerardii* on invasion resistance and productivity. *Plant Ecology & Diversity*, in press.

Avolio, M. and M.D. Smith. 2013. Mechanisms of selection: phenotypic differences among genotypes explain patterns of selection in a dominant species. *Ecology*, 94:953-965.

Avolio, M., J.M. Beaulieu, and M.D. Smith. 2013. Genetic diversity of a dominant C_4 grass is altered by increased precipitation variability. *Oecologia*, 171:571-581. (DOI 10.1007/s00442-012-2427-4)

Avolio, M., J.M. Beaulieu, E.Y.Y. Lo, and M.D. Smith. 2012. Measuring genetic diversity in ecological studies. *Plant Ecology*, 213:1105-1115.

Avolio, M.L., C.C. Chang, and M.D. Smith. 2011. Assessing fine-scale genotypic structure of *Andropogon gerardii* in the tallgrass prairie. *American Midland Naturalist*, 165:211-224.

Hoover, D.L., A.K. Knapp, and M.D. smith. Contrasting sensitivities of two dominant C4 grasses to heat waves and drought. *Plant Ecology*, in review.

Smith, M.D. 2011. The ecological role of climate extremes: current understanding and future prospects. *Journal of Ecology* 99: 651-655.

Smith, M.D. 2011. An ecological perspective on extreme climatic events: a synthetic definition and framework to guide future research. *Journal of Ecology* 99: 656-633. (Lead paper of Special Feature)

Smith, M.D. 2013. Climate extremes. In Seastedt, T. and K. Suding (eds), Water Volume, Climate Encyclopedia, Elsevier.

Presentations:

Smith, M.D. Conceptual understanding of the ecological consequences of climate extremes and extreme climatic events. CLIMMANI & INTERFACE Workshop, Mikulov, Czech Republic. (Invited talk)

Smith, M.D. Ecological consequences of climate extremes vs. extreme climatic events: a framework and future directions. Climate Extremes and Biogeochemical Cycles 2013, Seefeld, Austria. (Keynote)