2008-09 NCERA-101 Station Report - Crop Systems and Global Change Laboratory

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Impact Nugget:
USDA-ARS Crop Systems and Global Change Laboratory (CSGCL) evaluated uniformity of growth chambers, improved the ability of a crop model to simulate drought response based on growth chamber data, and tested various responses of several plant species to CO_2 enrichment and temperature acclimation. Major improvements that affect CO_2 control and fertigation delivery to several growth chambers were implemented.

New Facilities and Equipment:
-A micro-irrigation system was installed for 18 soil plant atmosphere research (SPAR) chambers at CSGCL facilities. The system provides selection of the fertigation/irrigation source to each chamber (100 L nutrient tank, municipal water supply, or common 3800 L nutrient tank), maintains minimum pressure of 60 psi to ensure flow rate uniformity, and allows automated control through solenoid valves. Each chamber uses 32 pressure compensated emitters to provide a range of flow rates (0-8 lph). Variable, water-driven pumps provide desired injection ratios when individual nutrient tanks are used.

-Six older Environment Growth Chamber (EGC, Chagrin Falls, OH) reach-in chambers were moved from the SPAR chamber facility to the Controlled Environment Facility (CEF) for continued use by CSGCL. All chambers were retrofit with CO_2 control systems that include injection of CO_2-enriched and CO_2-free air.

-EGC C3 controllers on 6 additional EGC chambers in the CEF were updated to TC2 models, and Barber Coleman hot gas valves were exchanged with Sporlan models. Two FTIR gas generators were added to the building CO_2-scrubbed air system (for a total of 9) and are being operated at a higher inlet air pressure to increase scrubbing capacity.

-Equipment purchases include a FieldSpec3 spectroradiometer and integrating sphere (ASD, Inc., Boulder, CO) and a LI-6400 portable photosynthesis system including fluorometer head (LI-COR Biosciences, Lincoln, NE).

Unique Plant Responses:
-Leaf curling around margins of potato terminal leaflets was observed in SPAR chambers with elevated CO_2 (800 ppm). The cause is thought to be a combination of nutrient and water stress brought on in part by reduced transpiration (and nutrient uptake) as a result of stomatal closure at high CO_2 (D.H. Fleisher; D.J. Timlin).

Accomplishment Summaries:
-Four SPAR chamber experiments were conducted with potato and corn using sand culture in order to quantify responses to one or more of the following factors: potassium (K), nitrogen (N), CO_2 enrichment, or temperature. Evidence of K stress in corn and potato were not observed at any CO_2 level. Results indicate that developing detailed subroutines for K stress in potato and corn models is not necessary under typical production conditions. Corn root growth and root length density in response to N were evaluated by planting corn in 152 mm diameter PVC tubes with N fertilizer applied at different depths. The main goal of these SPAR studies is to improve crop models developed for the purpose of studying agricultural management options. For example, subroutines to simulate drought stress effects on leaf expansion were incorporated in the corn model MAIZSIM. Leaf area data from several SPAR chamber experiments, with water stress as the treatment, were used to validate the routines (Y. Yang; J.A. Chun; D.H. Fleisher; D.J. Timlin; V.R. Reddy).

-The ability of important species to adapt to potential increases in CO_2 and changes in air temperature were studied in growth chambers at the CEF. Studies with *Arabidopsis thaliana* and *Brassica oleracea* evaluated the acclimation of net photosynthetic rate to temperature. Larger changes in the temperature dependencies of leaf level photosynthetic parameters were observed in *Brassica* as compared with *Arabidopsis*, indicating more capacity to acclimate photosynthetically to changes in growth temperature (J.A. Bunce). A study with rice showed that the effect of CO_2 enrichment on nitrogen (N) uptake capacity in roots depended on developmental stage and generally resulted in decreased nitrate and ammonium uptake during mid- and later-reproductive stages (H. Shimono; J.A. Bunce). Response, particularly floral sterility, of wild and cultivated rice lines to CO_2 and temperature were studied in growth chambers to evaluate adaption to CO_2 and climate extremes (L. Ziska).

-Experiments in the CEF were conducted to evaluate CO_2 and/or temperature effects on biochemical constituents in important plant species. Growth chamber studies to determine if CO_2 and/or temperature modifies concentration of secondary defensive compounds (e.g. nicotine) as a function of the C:N of the compound in tea, coffee, and Artemisia were conducted. The experiment tested the hypothesis that the concentration of compounds with higher N content would decrease with increasing CO_2 (L. Ziska). Effects of CO_2 enrichment on individual soluble amino acids and organic acids in barley leaves were examined in controlled environment chambers. Glutamine concentrations were decreased 70% in barley primary leaves that developed leaf yellowing in response to high light and high carbon dioxide levels. Elevated carbon dioxide and a mutation within NADH-dependent nitrate reductase decreased glutamine levels in vegetative stage barley leaves (R. Sicher). Such studies provide baseline information on how plant factors that influence quality and overall productivity may be influenced by climate change.

Impact Statements:

-An evaluation of a 12 SPAR chamber uniformity study was completed. No significant chamber affect was observed for total leaf area, yield, and total biomass production of wheat. Large within-chamber variations were significant and similar for all chambers, and were a result of variations in settling of growth media, wind speed, nutrient delivery, and shading of incident sunlight. Overall, when appropriate experimental protocols are followed and within-chamber positional effects are taken into account during sampling, individual chamber effects on plant responses can be minimized. These results have important consequences for statistical analysis and interpretation of SPAR chamber experiments.

-Using data primarily generated from SPAR chambers, routines for nitrogen and water stress were incorporated and validated in the USDA-ARS corn model MAIZSIM. MAIZSIM is a process level, explanatory crop model suitable for farmers, scientists, and policy planners interested in studying effects of different agricultural management strategies.

Published Written Works:

Blank, R.R., T.A. Morgan, L.H. Ziska, and R.H. White. 2008. Effect of atmosphere CO_2 levels on nutrients in cheatgrass tissue. USDA-FS, Rocky Mountain Research Station.

Bunce, J.A. 2008. Acclimation of photosynthesis to temperature in Arabidopsis thaliana and Brassica oleracea. Photosynthetica, 46: 517-524.

Fleisher, D.H., D.J. Timlin, and V.R. Reddy. 2008. Interactive effects of carbon dioxide and water stress on potato canopy growth and development. Agron. J., 100: 711-719.

Fleisher, D.H., D.J. Timlin, and V.R. Reddy. 2008. Elevated carbon dioxide and water stress effects on potato gas exchange, water use, and productivity. Agr. and Forest Met., 148: 1109-1122.

Shimono, H. and J.A. Bunce. 2009. Acclimation of nitrogen uptake capacity of rice to elevated atmospheric CO_2 concentration. Annals of Botany, 103: 87-94.

Timlin, D.J., K. Kuznetsov, D.H. Fleisher, S-H Kim, V. R. Reddy. 2009. Simulation of nitrogen demand and uptake in potato using a carbon assimilation approach. In (L. Ma, L.R. Ahuja, T.W. Bruulsema, eds.) Quantifying and Understanding Plant Nitrogen Uptake for Systems Modeling. CRC Press, Taylor & Francis Group, LLC.

Timlin, D., J. Bunce, D. Fleisher, V.R. Reddy, Y. Yang, S.-H. Kim, S.A. Saseendran, and B. Quebedeaux. 2008. Simulation of the effects of limited water on photosynthesis and transpiration in field crops: can we advance our modeling approaches? In (L.R. Ajuha, V.R. Reddy, S.A. Saseendran, and Q. Yi, eds.) Response of Crops to Limited Water: Understanding and Modeling Water Stress Effects on Plant Growth Processes.ASA, Inc., Madison WI, USA

Scientific and Outreach Oral Presentations:

Baligar, V.C., J.A. Bunce, and N.K. Fageria. 2008. Photosynthesis in tropical cover crop legumes influenced by irradiance, external carbon dioxide concentration and temperature. Plant-Soil Interactions at Low pH Conference, Guongzhou, China, Sept. 14-28.

Bunce, J.A. 2008. Elevated carbon dioxide alters the relative fitness of Taraxacum officinale genotypes. Ecological Society of America Meeting, Milwaukee, WI, August 2008.

Fleisher, D.H. 2008. Assessing uniformity in soil plant atmosphere chambers. 2008 International Meeting on Controlled Environment Agriculture, Cocoa Beach, FL, March 8-12.

Fleisher, D.H., D.J. Timlin, Y. Yang, and V.R. Reddy. 2008. Effects of stem density on potato at different CO_2 concentrations. ASA-CSSA-SSSA Meeting, Houston, TX, October 5-9.

Sicher, R.C. 2008. Effects of CO_2 enrichment on the metabolism of soluble amino acids and organic acids in barley primary leaves. ASA-CSSA-SSSA Meeting, Houston, TX, October 5-9.

Timlin, D.J., D.H. Fleisher, and V.R. Reddy. 2008. Quantifying leaf expansion and canopy development in potato as a function of nitrogen and CO_2. Biological System simulation Group Conference, Temple, TX, April 7-10.

Timlin, D.J., D.H. Fleisher, Y. Yang, and V.R. Reddy. 2008. Two dimensional simulations of light interception and soil water dynamics in row crops: a two dimensional approach. ASA-CSSA-SSSA Meeting, Houston, TX, October 5-9.

Yang, Y., D.H. Fleisher, D.J. Timlin, B. Quebedeaux, and V.R. Reddy. 2008. Evaluating the MAIZSIM model in simulating potential corn growth. ASA-CSSA-SSSA Meeting, Houston, TX, October 5-9.

Yang, Y., V.R. Reddy, S. Lokhande, J.C. Ritchie, D.H. Fleisher, D.J. Timlin, and B. Quebedeaux. 2008. Effects of potassium nutrition on physiological processes and derivative spectrum characteristics of corn plants. Biological System simulation Group Conference, Temple, TX, April 7-10.

Ziska, L.H. 2008. Photosynthetic potential, CO_2 and climate change: Challenges and Opportunities. Invited speaker. Bill and Melinda Gates Foundation Photosynthesis Meeting, Seattle, WA, July 8-9.

Ziska, L.H. 2008. Global climate change and invasive plants: threats and opportunities. ASA-CSSA-SSSA Meeting, Houston, TX, October 5-9.