**USDA-ARS Beltsville, Maryland 2021 Station Report**
NCERA-101: Committee on Controlled Environment Technology & Use

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**New Facilities and Equipment**

- A contract was awarded for 6 new Conviron PGC-FLEX growth chambers and 2 new walk-in BDW120 plant growth rooms to be installed in November, 2021 at the Controlled Environment Facility (CEF) located in Beltsville, Maryland. The CEF currently includes 21 actively managed growth chambers. These include 10 reach-in style EGC units equipped with HID lamps, 2 walk-in EGC units with fluorescent lamps, 7 Biochamber reach-in style units originally equipped with HID lamps, and two smaller Biochamber units with LED lamps. In response to an energy conservation push, USDA retrofitted the HID light canopies in the 7 Biochamber units with LED lamps. The new Conviron units will also be equipped with LED lamps of the same spectral quality. A set of six obsolete EGC reach-in units exceeded their life-cycle (purchased in the 1980s) and were removed from the facility. Moving forward into 2022, CEF will include 23 actively managed growth chamber units.
- Improvements related to outdoor chiller and cooling tower operations were implemented at the Soil-Plant-Atmosphere-Research (SPAR) facility. These included upgraded software systems to improve chiller control actions and new loop temperature and coolant flow sensors which together reduce energy consumption. A set 18 new LI-7000 $CO_2$/$H_2O$ gas analyzers (LI-COR Biosciences) were installed to replace older style, obsolete, LI-6262 units. A new $CO_2$ scrubbing system was recently purchased to provide $CO_2$ free air to assist in maintaining desired set-points during the night-time in the SPAR chambers. The system will be integrated in 2022. In total, the SPAR facility includes 18 outdoor SPAR chamber units and six reach-in style Biochamber units with HID lamps.
- Two adjacent mini-greenhouse units which utilize forced air systems for heat were retrofit with $CO_2$ control along with data acquisition system and sensors for measurement of photosynthetically active radiation, relative humidity, air and soil temperature, and time-domain reflectometry (TDR) soil water content data. Climate data is logged at 30 second intervals while TDR data is recorded manually per end-user control.
- A new OctoFlox rugged multi-target SIF/hyperspectral reflectance spectrometer (JB – Hyperspectral) which will assist studies related to high throughput greenhouse phenotypic system related to measuring SIF (solar induced fluorescence) and reflectance. A Pika L hyperspectral camera (Resonon) was also purchased for this phenotyping work along with a RSE 600 (Fluke) thermal imaging camera.

**Unique Plant Responses**

- Grain chalk expression from a U.S. rice hybrid variety was observed to increase as much as 40% in response to short-term heat stress (+4 or +8°C above the 28/23°C setpoint thermoperiod) applied for 14 days during grain filling. Grain fill percentage declined as much as 50% as a result of the extreme heat event, which in turn was associated with substantial decline in grain yield. Growth under elevated $CO_2$ (740 ppm) slightly compensated for negative heat impacts on yield, but may have exacerbated chalk expression which negatively impacts grain quality. Research was conducted in six SPAR Daylit chambers.

- An experiment was conducted to evaluate the response of Parthenium, an invasive species, to $CO_2$ concentrations using two walk-in Biochamber growth cabinets. The weed was observed to grow faster and produce more parthenin (which reduces productivity of crop fields and pastures and is a cause of dermatitis in humans) with rising $CO_2$ levels as compared to a non-invasive biotype. This suggested that the current levels of $CO_2$ contributed to the plant's global invasiveness and toxicity. This information will allow for assessing better weed control strategies and provides ecological information on subspecies variation.

**Accomplishment Summaries**

- An artificial intelligence algorithm and an improved corn model, MAIZSIM, were constructed that more accurately predict effects of decaying cover-crop mulch residue, and effects of tillage, on soil characteristics. These tools can predict crop biomass and changes in soil nitrogen and water content through both cover- and cash- crop growing seasons and permit more realistic assessment of mult-year cropping rotations. Soil, environment, plant genetics, and climate change effects on cover crop performance can be evaluated for specific locations. This work is being used collaboratively with scientists at USDA-ARS, University of Maryland, and North Carolina State University to develop a set of best cover crop management guidelines /

- The U.S. is the fifth largest rice exporter in the world. Negative effects on grain yield and quality due to warming temperatures are occurring, and future projections indicate temperatures are likely to increase by several degrees. Simulations from a newly developed rice model showed declines in yield up to 20% based on 2040 climate predictions. These yield variations were correlated with rising temperatures and negative impacts on grain were slightly offset by elevated $CO_2$. Location specific adaptation strategies can be developed by growers, including adjusting planting dates to avoid heat during anthesis and cultivar selection. These simulations are of interest to the U.S. rice breeders and farmers and can be used for identifying phenotypic traits ideal for location specific cultivar breeding.

**Impact Statements**

- Process-based models for rice (RICESIM), soybean (GLYCIM), and cotton (GOSSYM) were improved using experimental data generated at USDA. A new interface tool, Crop Land and Soil SIMulator (CLASSIM), was developed and integrated with these models. CLASSIM is used by national and international collaborators at USDA-ARS, University of Nebraska, University of Maryland, North Carolina State University and Taiwan for evaluating G x E x M strategies that influence crop sustainability at various field locations.

**Published Written Works (selected peer-reviewed for FY21)**

Barnaby, J., Kim, J., Jyostna, M., Fleisher, D., Tucker, M., Reddy, V., and Sicher, R. Varying atmospheric $CO_2$ mediates the cold-induced CBF-dependent signaling pathway and freezing tolerance in Arabidopsis. 2020. International Journal of Molecular Sciences. DOI:10.3390/ijms21207616.

Fernandez-Baca, C.P., McClung, A.M., Edward, J., Codling, E.E., Reddy, V.R., and Barnaby, J.Y.* Genotype and water management impacts on mitigation of inorganic arsenic in rice. Frontiers in Plant Sciences. 11: 2284. 2021. https://doi.org/10.3389/fpls.2020.612054

Fernandez-Baca, C.P., Rivers, A.R., Maul, J.E., Kim, W.J, McClung, A.M., Roberts, D.P., Reddy, V.R., and Barnaby, J.Y.* Rice Plant-Soil Microbiome Interactions Driven by Differential Root and Shoot Biomass. Diversity. 13 (3): 125. 2021. https://doi.org/10.3390/d13030125

Fernandez-Baca, C.P., Rivers, A.R., Kim, W.J, Iwata, R., McClung, A.M., Roberts, D.P., Reddy, V.R., and Barnaby, J.Y.* Changes in rhizosphere soil microbial communities across plant stages of high and low methane emitting rice genotypes. Soil Biology and Biochemistry. 108233. 2021. http://doi.org/10.1016/j.soilbio.2021.108233

Fleisher, D.H., Condori, B., Barreda, C., Berguijs, H., Bindi, M., Boote, K., Craigon, J., van Evert, F., Fangmeier, A., Ferrise, R., Gayler, S., Hoogenboom, G., Merante, P., Nendel, C., Ninanya, J., Pleijel, H., Raes, D., Ramirez, D.A., Raymundo, R., Reidsma, P., Silva, J.V., Stockle, C.O., Supit, I., Stella, T., Vandermeiren, K., van Oort, P., Vanuytrecht, E., Vorne, V., and J. Wolf. Yield response of an ensemble of potato crop models to elevated $CO_2$ in continental Europe. 2021. European Journal of Agronomy. https://doi.org/10.1016/j.eja.2021.126265

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Li, S., Fleisher, D.H., Timlin, D.J., Reddy, V.R., and Wang, Z. Application of a coupled model of photosynthesis, stomatal conductance and transpiration for rice leaves and canopy. 2021. Computers and Electronics in Agriculture https://doi.org/10.1016/j.compag.2021.106047 Log No.

Li, S., Fleisher, D.H., Timlin, D.J., Reddy, V., Wang, Z., Mcclung, A.M. 2020. Evaluation of Oryza and Ceres-Rice in simulating rice development and yield in the U.S. Mississippi Delta. Agronomy Journal. https://doi.org/10.3390/agronomy10121905.

Mathur, S., Sunoj, V., Elsheery, N.I., Reddy, V., Jajoo, A., Cao, K. 2021. Regulation of Photosystem II heterogeneity and photochemistry in two cultivars of C4 crop sugarcane under chilling stress. Frontiers in Plant Science. 12:627012. https://doi.org/10.3389/fpls.2021.627012.

Wang, Z., Timlin, D.J., Yuki, K., Chenyi, L. Sanai, L., Yan, C., Fleisher, D.H., Tully, K., Reddy, V.R., and Horton, R. The concept of time domain reflectometry piecewise analysis for electrical conductivity computation. 2021. Computers and Electronics in Agriculture, 182: https://doi.org/10.1016/j.compag.2021.106012 .

## Other relevant activities or information

- Two new scientists were hired by the Adaptive Cropping Systems Lab in 2021. Dr. Christine Chang is a research plant physiologist with a focus on plant stress measurements and Dr. Kirsten Paff is an agricultural engineer with a focus on crop modeling with regards to food security issues.