

NCERA-101 Station Report from Syngenta, 2014

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1. New Facilities and Equipment

In May 2013, Syngenta inaugurated the Advanced Crop Lab in the Research Triangle Park innovation center. The objective of this new site is to improve controlled environment capabilities to conduct high-precision and high-throughput plant phenotyping.

At the 2014 NCERA-10 Annual Conference, we presented two posters that describe two technologies contributing to these enhanced capabilities: (i) a precision irrigation based Whole Plant Phenotyping System (WPPS) (Figure 1) and (ii) a sealed precision chamber system (Figure 2). The WPPS was developed in collaboration with Argus Controls, Advances Control Solutions (?), and Marc van Iersel (University of Georgia). The Precision Chamber technology was developed in collaboration with Mike Stasiak and Mike Dixon (University of Guelph).

2. Unique Plant Responses

3. Accomplishment Summaries

4. Impact Statements

5. Published Written Works

A whole-plant phenotyping approach leveraging Syngenta's Advanced Crop Laboratory at the Research Triangle Park Innovation Center

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NCERA-101 Annual Conference

Fairbanks, April 12-15, 2014

Background & Objectives

The precise control of plant irrigation is a technology developed by the horticulture industry to provide (i) optimized plant health (ii) water input management solutions.

Precision irrigation technology relies on the programed water supply triggered by a water status sensor acting as a feedback-control.

We present here applications of this technology for the industrial phenotyping of crop plants. Specifically, this work describes how we are able to measure (i) plant transpiration, (ii) total water use, and (iii) fresh biomass gain.

This system provides an advanced whole-plant phenotyping system that will be implemented in our new controlled environment facilities.

Inspiration from NCERA-101 and horticulture

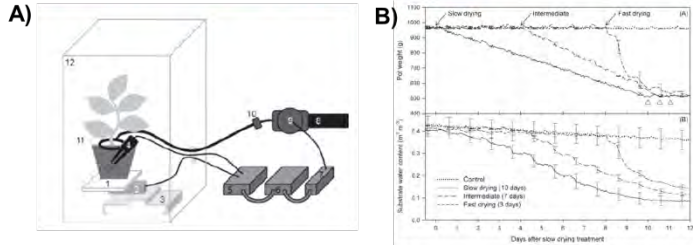


Fig. 1: Advanced feedback-controlled irrigation developed for plant physiology research and horticultural production (Kim & van Iersel (2011) *Physiol Plantarum* 143:166)

A) Components of a precision irrigation system: (1) Acrylic plate, (2) load cell, (3) load cell support, (4) soil moisture sensor, (5) multiplexer, (6) datalogger, (7) relay driver (8), water source, (9) solenoid valve, (10) pressure compensated emitter, (11) circular drip tube.

B) The setup allows for precision control of drought stress treatment. Soil moisture was controlled here by weight and is monitored both as pot weight and volumetric water content (VWC).

Leveraging precision irrigation for plant physiology measurements

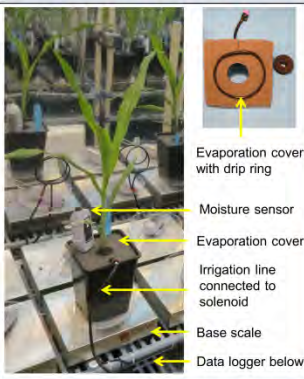


Fig. 2: A precision irrigation system combining soil moisture reading with mass balance measurement.

Irrigation can be **feedback controlled** using either moisture sensor derived volumetric water content (VWC) or scale-derived weight set points.

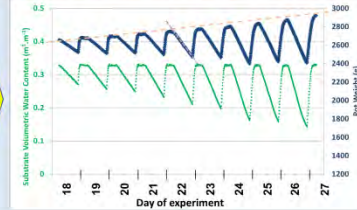


Fig. 3: Moisture sensor-controlled irrigation and pot weight response.

A well-watered maize plant population (N=4) was monitored for a 10-day period between V4 and V6 growth stages and irrigated to a fixed VWC set point ($0.325 \text{ m}^3 \text{ m}^{-3}$) during the night. The green line shows the average VWC curve and the blue line shows the average pot weight response.

Plants were grown in a small Conviron growth chamber under $450 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ PPFD, 16 hr light photoperiod, $22/27^\circ\text{C}$ temperature and $1.25/1.75 \text{ kPa}$ VPD night/day.

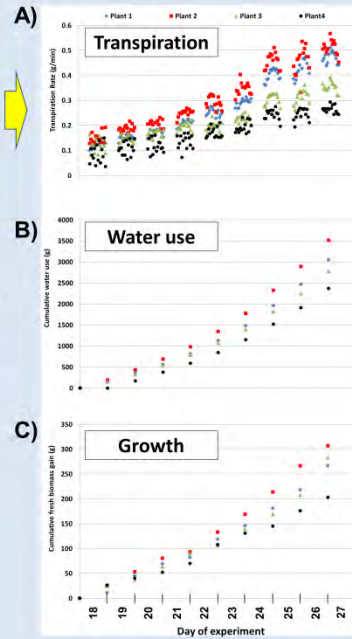


Fig. 4: Real time measurement of three plant responses

- A) **Hourly transpiration rate** during the light period was calculated by dividing pot weight loss over time (purple dashed line in Fig.3)
- B) **Cumulated water use** since day 18 of the experiment. This amount was calculated by summing the daily amount of water added to the substrate to replenish the water used during the day + the plant demand during the night.
- C) **Cumulative fresh plant biomass gain** was calculated by adding the difference in pot weight between 6AM of two consecutive days when substrate soil moisture equaled $0.325 \text{ m}^3 \cdot \text{m}^{-3}$ and summed day after day (orange dashed line in Fig.3).

Implementation for industrial plant phenotyping

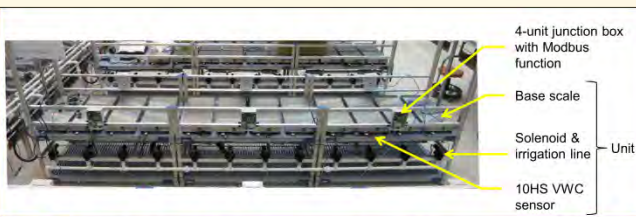


Fig. 5: R&D project with Argus Environmental Controls to develop a Modbus system controlling 4 base scales at a time.

Modbus protocol allows for each base scale to share common wiring while maintaining a unique identifier to each base scale. **Junction boxes provide for analog to digital signal conversion and Modbus data transfer to server.** This allows the scalability of the system. 10HS VWC sensors (Decagon Devices) & thermocouples tie into Argus Titan multiplexer & I/O modules while irrigation solenoids tie into relay drivers. Each base scale, VWC sensor, & solenoid station can be independently controlled through Argus Titan interface software. Thermocouples allow for temperature compensation of weight during daily environmental changes.

Programming of the system will allow high control of water input and the application of various drought treatments as shown in Fig 1.B.

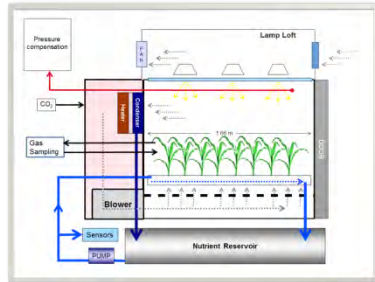
Figure 1. Syngenta poster presented to the NCERA-101 2014 conference describing the development of a new whole-plant phenotyping system that combine load cell, moisture sensor, and feedback controlled irrigation technologies for detailed studies on plant water use.

Closed-chamber technology for whole plant characterization

Tricia Costello^a, Michael Stasiak^b, Michael Nuccio^a, Matthieu De Carbonnel^a

This technology makes precise measurements of subtle changes in plant response to an environment in a non-invasive manner. These programmable environments continuously monitor photosynthesis of a plant population in real time. Detection of differences in plant growth characteristics is possible in significantly less time compared to conventional methodologies.

Chamber schematic



Chamber installation



Control software monitors and records data from over 50 sensors in each chamber

Raw CO₂ data

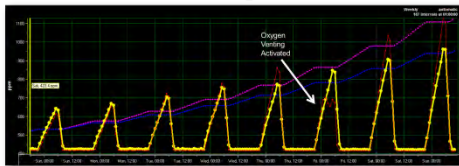


Figure 1. Argus data feed depicting CO₂ concentration in ppm (red and yellow) in two chambers and CO₂ volume (mmol) injected to maintain a steady-state environment (purple and blue) over one week period.

Oxygen Venting

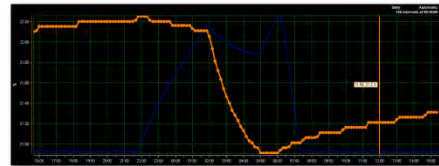


Figure 2. Argus data feed showing atmospheric O₂ (percent, orange) and CO₂ (ppm, blue) during a venting cycle. Oxygen is vented during a three hour period at night when levels exceed a set point, in this case 22%.

Enabling instantaneous measurements of physiological responses to the environment

Respiration and Re-assimilation

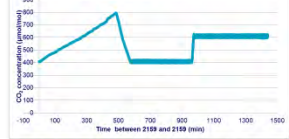


Figure 3. Data from a single day depicting CO₂ changes as a result of plant respiration (increasing), re-assimilation (decreasing) and steady-state photo-assimilation under two different set points (flat lines at 400 ppm and 600 ppm).

Steady-State Photo-assimilation

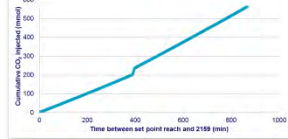


Figure 4. Data from a single day depicting CO₂ injections required to maintain a set concentration within a chamber. At 400 minutes of photo-assimilation, the set point is adjusted from 400 ppm to 600 ppm, altering the injection rate of CO₂.

Transpiration

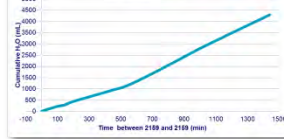


Figure 5. Data from a single day depicting cumulative transpiration in mL. Values are corrected for evaporation. Note the rate change between dark hours (0-500) and light hours (500-1500).

Using rate calculations to generate daily comparative data during early in maize development (V3-V6)

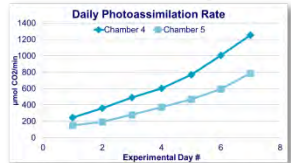


Figure 6. Photo-assimilation rate comparisons between two chambers over the course of an experiment. Note the higher rate and accelerating trend in chamber 4 compared to chamber 5.

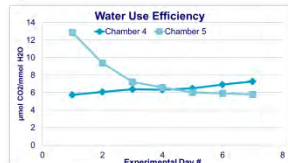


Figure 7. Water use efficiency on a daily basis, compared between two chambers during an experiment. Note the opposing trends in chamber 4 and chamber 5.

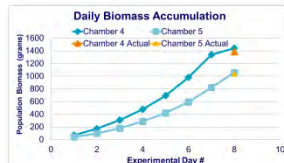


Figure 8. Daily biomass accumulation calculated from CO₂ consumption, along with actual aerial biomass measurements taken at the end of the experiment.

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Figure 2. Syngenta poster presented to the NCERA-101 2014 conference describing the Precision Chamber technology.