Studying cotton water uptake after short rain events
Los Gatos Research (LGR)

Introduction
Quantifying rainwater uptake by plants is essential to optimize crop production in rain-fed agriculture. But, until recently, instrumentation was unavailable to examine the dynamics of shorter rain events, such as those amounting to accumulations of less than 25 mm.

Agricultural researchers have been looking for ways to broaden understanding of how quickly small amounts of rainwater that infiltrates the soil passes into plants via rootwater uptake.

Since this rainwater typically has a different isotope ratio than the groundwater, researchers can use water isotope measurements to determine rainwater infiltration.

However, such studies require fast-acting, water isotope ratio analyzers with high sensitivity and the ability to study numerous samples.

For more information
Further details of ABB Measurement & Analytics products are available for free download from: www.abb.com/measurement

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Solution

The Liquid Water Isotope Analyzer from Los Gatos Research, a member of the ABB Group, enables this kind of research. These analyzers take advantage of a patented, cavity-enhanced absorption spectroscopy termed Off-Axis Integrated Cavity Output Spectroscopy (Off-Axis ICOS). This technology can quickly measure water isotope ratios in large numbers of plant samples, allowing for the study of small rain events on plants.

Off-axis ICOS analyzers consist of an optical resonant cavity with highly reflective mirrors (reflectance R greater than 99.9 %) at each end. The light passes through the initial mirror and reflects back and forth in the cavity for a prolonged time. This results in a very long effective optical length (> 12 miles) with enhanced molecular absorption, allowing for ultra-high sensitivity in a relatively small setup.

Off-axis alignment into the cavity prevents both optical interference within the cavity and optical feedback to the laser from the mirrors. The tunable diode laser turns on, scans over the absorption features and turns off, providing a full absorption spectrum in an extremely short measuring time (1 – 10 ms or 100 – 1000 Hz).

Unlike alternative cavity enhanced techniques, the performance of the OA-ICOS analyzer does not depend on hyper-critical optical alignment. Its performance is virtually immune to vibrations, small physical shocks and changes in temperature and pressure. Moreover, maintenance of the optical system may easily be done by the user.

One complication of using cavity-enhanced spectroscopy to analyze water from plant extracts is the interference caused by the -OH bonds from organic compounds. These compounds, such as methanol, ethanol and organic acids, will co-distill with the plant water, leading to erroneous isotope ratios. Los Gatos Research’s Spectral Contaminant Identifier software evaluates the level of contamination in a sample and it is possible to calibrate the LGR isotope ratio analyzer to remove the effects of these contaminants on data.

This study (Agricultural Sciences 5, 2014, 170-177) took place in the Cropping Systems Research Laboratory, USDA-ARS, in Lubbock, Texas, USA. The goal was to determine root-water uptake of rainwater with accumulations of less than 25 mm. This requires knowing the amount of time it takes for a plant to uptake the rainwater and move from the roots through the xylem to the leaves. In particular, it looks at the time that it takes for enriched isotopic water, compared to irrigation water, to reach the petioles in the meristem of cotton plants in a greenhouse environment.

The research requires dosing the plant with isotopically enriched (or depleted) water to distinguish its effects from the control-source (irrigation) water. Enrichment of water with δ18O took place over 20 days via evaporation (light water evaporates faster than heavy water.) The experiments were carried out in a greenhouse environment. Extraction of the water from the cotton petioles (the leaf stems) was achieved via a well-documented cryogenic technique with vacuum distillation.

Figure 1 Cotton plants grown in the greenhouse for the rain event studies.
Results

The greenhouse experiments showed full equilibration of the enriched source water and control within 14 hours, as indicated in Figure 2. Divergence from the control plants took place in as little as 4 hours.

This suggests that the uptake of rainwater by cotton plants from rain events 25 mm or less can be observed in as little as a few hours after a rain event. It is unnecessary to obtain samples for more than 24 hours. Obtaining frequent samples after a rain event would be more desirable.

This knowledge will make possible future investigations into rainwater uptake by crops under different management practices, especially non-irrigated dryland crops such as cotton. Information such as this is essential in dryland agriculture and in areas where irrigation water is declining, such as the Southern High Plains of Texas, USA. In this area most of the rain occurs during the growing season and about 50 % of individual rain events are less than 6 mm.

![Figure 2](image)

**Figure 2**  Uptake of isotopically enriched water versus that of tap (control) water sampled every two hours

References

Based on ‘Time for cotton to uptake water of a known isotopic signature as measured in leaf petioles,’ by Timothy S. Goebel, Robert J. Lascano, Agricultural Sciences 5 (2014) 170-177.