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Historical overview of John M. Norman's involvement in the development of several key instruments for biophysical measurement

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ABSTRACT

If you have ever used a quantum sensor, or measured the LAI of a plant canopy, or lugged around a portable photosynthesis system, then you are likely the beneficiary of just some of John Norman's work in instrumentation. In his nearly 40-year career of trying to understand plants and their environment through modeling and measurements, John's boundless creativity and enthusiasm have never let lack of available instrumentation stop him for long. He leaves behind an impressive wake of gadgets and devices. Most served their purpose, and provided the missing information being sought. Some of his devices have gone on to world-wide success, while others are found only in the dust of former students' memories. John's legacy, however, is clear, and goes well beyond instrumentation: he is a joyful, creative resource, as all who have had the privilege of knowing him can attest.

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1. Introduction

Professor John Norman has had a long and fruitful history of instrumentation development. A list of the devices he has contributed to include:

- Quantum sensor (Norman et al., 1969)
- Various traversing devices for measuring sunflecks in canopies (Miller and Norman, 1971; Perry et al., 1988; Norman and Jarvis, 1974)
- Drag anemometer for turbulence measurements (Norman et al., 1976; Perry et al., 1978)
- An aerosol sampler (Pena et al., 1977)
- A real time computer graphics system for forecasting (Cahir et al., 1981)
- Microlysimeter for measuring ET and drainage (Cook and Norman, 1982)
- Root length measuring device (Wilhelm et al., 1983)
- DEMON, the CSIRO Leaf Area Index instrument (Lang et al., 1985.)
- A portable CO_2 calibration device (LI-COR literature)
- A jig for measuring bidirectional reflectance from leaves (Norman et al., 1985)
- The "Pine Cone" sensor, a device for measuring the angular distribution of diffuse radiation above and within canopies (Hutchison et al., 1986)
- Lighted bar or light-pipe used at night in turf (Kopeck et al., 1987)
- A field portable photosynthesis system (McDermitt et al., 1989)
- LAI-2000 Leaf Area Index instrument (Welles and Norman, 1991)
- Soil respiration chamber (Norman et al., 1992)
- A device for measuring directional emissivity (Norman et al., 1994)
- A device for measuring the water holding capacity in pork (Kim et al., 1995)
- Heated needle anemometer (Bland et al., 1995)
- Multiband vegetation imager (Kucharik et al., 1997)
- Equilibrium tension lysimeter (Brye et al., 1998)
- A high precision infra-red radiometer (Baker and Norman, 1999)
- A soil and topography mapper (Zhu et al., 2004)
- A device for measuring field-scale runoff (Bonilla et al., 2006)

This paper looks at some of these devices from the early part of John's career, and shares the story of how they came about.

2. Early career

John Norman received a Bachelors degree in Physics and an M.S. in Soil Physics at University of Minnesota. In 1967, he started on his PhD at the University of Wisconsin, working under Dr. Champ Tanner on light distribution and canopy architecture in plant canopies. One of John's first efforts was to develop a silicon cell PAR sensor (Norman et al., 1969). This was later improved by LI-COR and marketed as the LI-190 quantum sensor. In analyzing light measurements made under a corn canopy, John recognized that there was significantly more radiation under the canopy than the

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conventional gap-fraction approach could explain. With Dr. Ed Miller from the Physics Department, it was determined that light from the penumbra of the sun was not being accounted for in the standard theory (Miller and Norman, 1971; Norman et al., 1971).

John received his PhD in March 1971 and embarked on a post-doctoral position in the Botany Department at the University of Aberdeen under Dr. Paul Jarvis, addressing the effects of clumped canopy architecture in Sitka spruce (Norman and Jarvis, 1974, 1975). In 1972, John was offered a position at Penn State to work on canopy–atmosphere interactions, joining a group of micrometeorologists including Dr. Dennis Thomson and Dr. Hans Panofsky. John took on a wide range of projects at Penn State, from developing a drag anemometer for measuring in- and above-canopy turbulence, to modeling the effects of orchard heaters used for frost protection (Fig. 1). It was at this time that John also began work on a career-long endeavor, development of the soil–plant–atmosphere Cupid model (Norman, 1979; Norman and Campbell, 1983; Norman and Arkebauer, 1991), which would come to embody the insights accumulated from his own and others' work in this continuum.

3. Carbon exchange

3.1. Porometry

In 1978, John took a faculty position in the Agronomy Department at the University of Nebraska – Lincoln. Lincoln was also the home of a small company named LI-COR. John visited them during his interview trip, and met the owner Bill Biggs who shared John's interest in quantum sensors. LI-COR also had made a series of porometers over the years (LI-60, LI-65), and was working on an instrument that became the LI-1600 steady state porometer. John was interested in porometers and the insight they provide about stomatal functioning, and had purchased a Delta T Mark II porometer with some of his start-up money. Soon, John was working with LI-COR to do a formal comparison of all of these porometers (Fig. 2).

The results of the comparison (Fig. 3) showed good agreement between the LI-1600 and the Delta T, but also clearly showed that the LI-65 had problems. As a result, LI-COR discontinued its production. Interestingly, this move met with customer resistance, since many liked the low price, and did not mind the uncertain results.

3.2. Portable photosynthesis instrumentation

At about this time, researchers (e.g. Farquhar et al., 1980) began to demonstrate the role that leaf photosynthesis plays in stomatal behavior, and it became clear to John that simple porometer measurements would never be sufficient to fully understand stomatal function. The sorghum physiology group at the University of Nebraska had been using a field technique involving large chambers and syringes to estimate carbon uptake in the field (Clegg et al., 1978). The plant part to be measured was enclosed in a

Fig. 1. John Norman, circa 1977, getting photographic documentation of canopy structure in an orchard.

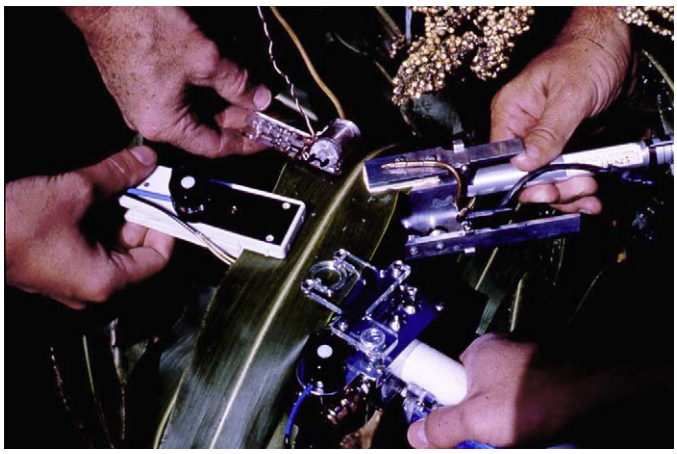

Fig. 2. Porometer comparison conducted by John Norman. Shown are the LI-COR LI-65 (upper left), Delta T Mark II (lower left), a Kaufman convective chamber porometer (upper right), and the LI-COR LI-1600 steady state porometer (lower right).

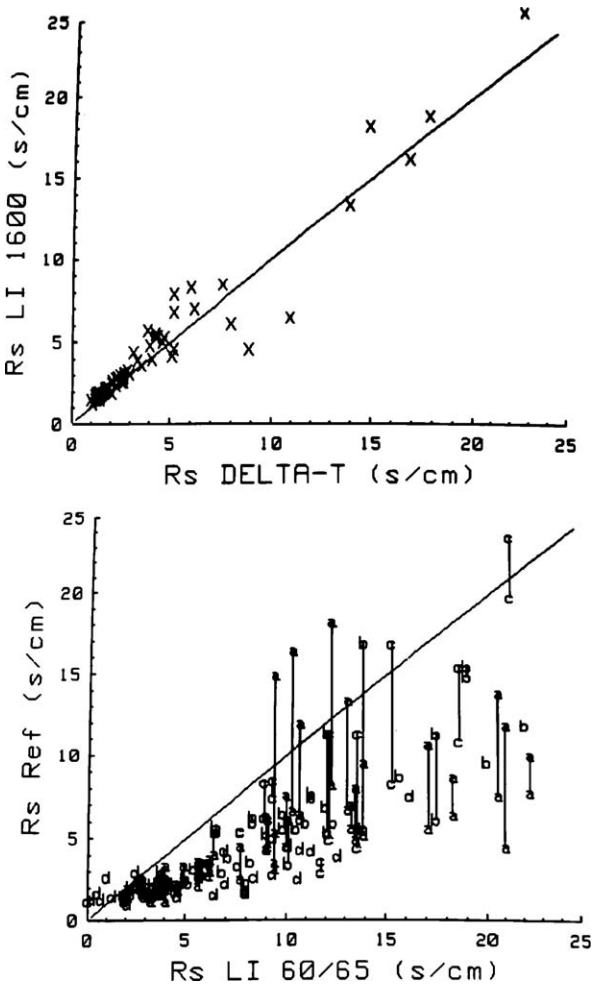

Fig. 3. (Top) Comparison between the Delta T and LI-1600 porometers. (Bottom) The LI-65 had problems, and LI-COR discontinued production.