Into the Field

How advances in instrumentation technology has allowed agronomic research to move out of the laboratory and into the field.

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Being able to feed the world's increasing population is one of the fundamental priorities of the global community. Understanding crop production, plant biochemical activity and the plant's interaction with its changing environment, therefore, is a high priority with both national and multi-national administrations.
Prior to the 1950s, the only way that many researchers were able to assess plant growth was to dig the plant up and weigh it on returning to the laboratory; a rather crude, unreliable and impractical technique.

Back in the 1970s

A significant step forward in plant science research was the development of the infrared gas analyser, often affectionately known by researchers as an "IRGA". First produced in the UK in the 1940s, IRGAs measure energy absorbed by heteroatomic gases and vapours at very precise wavelengths within the infrared region.
Two such heteroatomic gases of significant interest to plant scientists are carbon dioxide (CO_2) and water vapour (H_2O). By measuring these gases, it is possible to monitor photosynthesis and transpiration, the two key biophysiological processes of a plant. During photosynthesis, carbon dioxide is taken up by the leaf and during transpiration, water vapour passes out of the leaf. The result is a change in the gas concentrations in the ambient air in close proximity to the leaf. If the rate of these changes is accurately measured then it can be used to provide an accurate indication of biochemical activity and growth efficiency of the plant. This type of measurement is often referred to as gas exchange.
The first IRGA specifically designed for plant science research was the ADC225 laboratory analyser introduced in 1971. Researchers throughout the world were now able to accurately measure photosynthesis and transpiration without damaging the plant material. The availability of these highly accurate and reliable laboratory instruments greatly enhanced our understanding of the fundamentals of plant physiology and plant growth.
However these single gas instruments were mains powered and were sensitive to vibration. Bulky and weighing over 27kg, these early analysers were very much confined to the laboratory.
To be able to apply our increased knowledge of plant physiology to improving our understanding of crop growth, research must be carried out in the field, in normal growth conditions. To do this required the development of a new generation of portable gas exchange equipment.

Figure 1. " Early portability, the ADC225 and bearers".

Going portable

The most critical stride in providing researchers with field portable instrumentation was the development of smaller, vibration insensitive optical technology for the infrared gas analysers. This involved utilising a single optical cell, which is primed with carbon dioxide free gas as a zero against which reference and analysis air can be sequentially measured. The "reference" being the air measured prior to the leaf, while the "analysis" is the air being measured after the leaf. The "differential" (reference-analysis) is the effect of the leaf on the close proximity ambient air. This single optical cell technique provides very accurate measurements in a highly portable and power efficient format. The first portable IRGA of this type was the ADC LCA-2 Portable Photosynthesis system, introduced in 1984.
To allow a single instrument to measure both carbon dioxide and water vapour exchange these instruments were fitted with humidity sensors to complement the carbon dioxide IRGA.
The complete system consisted of several other components as well as a battery operated IRGA. A separate data logger was provided not only to store data, but also to automatically calculate photosynthesis rate, transpiration rate and other related parameters. A flow control unit maintained a continuous supply of ambient air to the system. A selection of specially designed leaf chambers allowed physiological measurements to be made on a variety of plant species.
In addition to gas exchange data, the LCA-2 also incorporated sensors to measure air and leaf temperature and light concentration in the photosynthetically active radiation region (400nm – 700nm).
Not only was equipment now field portable it was also providing researchers with more information to interpret.
The result was that the physiology of a plant could now be directly equated to the ambient environmental conditions.

Global climatic change

Over the past 20 years the nature of agronomic research has evolved to reflect the growing international concern in global climatic change and how increasing atmospheric carbon dioxide concentrations could affect global crop production. Instrumentation has therefore been developed to allow scientists to directly address these issues. Fundamentally, equipment has become yet more field portable, more sophisticated and easier to use.

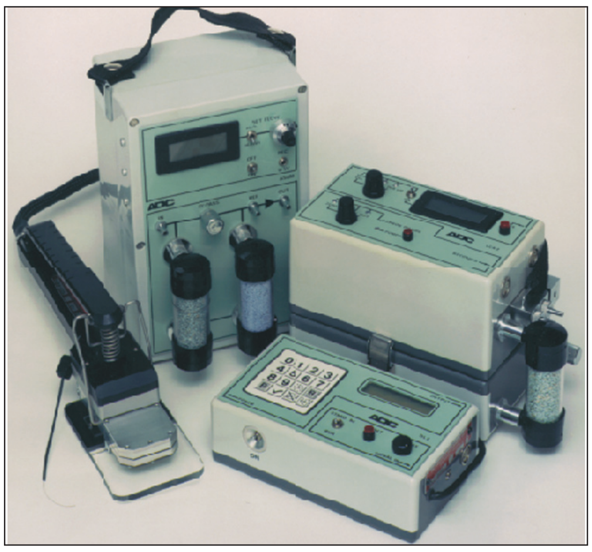

Figure 2. LCA2 "The first portable system".

One such gas exchange instrument that truly reflects these trends is the new LC*pro-SD* manufactured by ADC BioScientific Ltd.
The LC*pro-SD*, introduced in 2011, consists of only a small console weighing 4kg and a plant leaf chamber.
Miniaturisation of the IRGA has now developed to such an extent that the analysis cell is now housed in the leaf chamber directly next to the leaf. The response time, therefore, from when the plant undergoes gas exchange to when the analyser is able to measure these changes is greatly reduced.
It is now possible to accurately and automatically control the environmental conditions within the chamber.
Carbon dioxide, water vapour, temperature and light levels can all be programmed at single concentrations or at multiple steps, above or below ambient conditions. This is a key requirement for many contemporary environmental research projects.

The generation of A/Ci curves is one of the most common experiments that is currently being performed for assessing the effects of increasing atmospheric carbon dioxide concentrations on plant growth. Current ambient air carbon dioxide concentration is about 389ppm.
Many scientifically generated models predict that the imbalance between carbon emissions and carbon sinks, such as oceans and forests, will mean a doubling in ambient carbon dioxide concentrations in the next 40 years. There is therefore significant concern regarding how such predictions could alter global plant growth and crop production.
The A/Ci experiment involves measuring photosynthesis rate and related parameters at a range of above current ambient carbon dioxide concentrations. From this data it is possible to assess the efficiency of a plant to take in and utilise carbon dioxide at these potential higher ambient concentrations.
All data and experimental programs are stored on easily exchangeable SD cards providing unlimited data storage.

Figure 3. "Portable analysis today: the LCpro-SD in the field".

Increased versatility

The development of new types of chambers means that more types of crop species can be more easily investigated including grasses, conifers and even whole plants.
Gas exchange chambers can now be combined with optical fluorometers providing researchers with even more information and data on a plant's ability to utilise sunlight; a comparatively new technique developed for analysing environmental stress on a plant. Many portable gas exchange systems can also be easily adapted to measure soil respiration (CO_2 emissions from soil), an increasingly important parameter in the investigation of rising ambient carbon dioxide concentrations.

The future

Predicting the future is very difficult, but it is apparent that the driving forces for agronomic research for the foreseeable future will continue to be issues relating to global climatic change.
It is difficult to believe that the trend for evermore portable, sophisticated and easy to use equipment will not continue.
It is possible that increased collaboration between different research disciplines will occur. Plant physiologists and molecular biologists are already working together to apply cellular research findings on species such as Arabidopsis to whole plant activity in field conditions.
As in most scientific subjects, future experimentation will only be restricted by the researcher's imagination and the instrumentation available to them. It will be up to the manufacturers to continue to respond to the new and changing challenges placed on them by researchers driven by international political concerns.