News from the World of Microanalysis

German scientist develops innovative measuring method with significant advantages for research and industrial applications

Science is the art of small steps. Research results tend to be much like small pieces of a puzzle that can only produce a whole once they are all together in a global context. During the course of his dissertation, German biologist Dr. Stephan Blossfeld developed a novel method that not only followed this tradition, but that also contributed extraordinary benefits to research and industrial applications and that garnered quite some attention in scientific circles.

Fig. 1: Dr. Stephan Blossfeld, Biologist

Admittedly, the subject of Dr. Stephan Blossfeld's first paper from 2007, which was part of his dissertation, will sound a little less exciting for laypeople. Granted, a "novel, non-invasive optical method for the quantitative measurement and visualization of pH dynamics in the rhizosphere of plants" doesn't exactly sound like man landing on the moon. But if the method can enable scientists in the future to determine how metabolic processes in soil evolve across long periods of time and which parameters are responsible for their changes through the use of relatively simple but extremely precise instruments - well, that already makes for a very "exciting story". A story that began at the University of Düsseldorf, where Blossfeld was trying to find a challenging subject for his dissertation at the Geobotany Department in 2005.

The Story So Far

For geobotanists and other biologists whose work focuses on analyzing vegetation (particularly in soil), oxygen and carbon dioxide contents and pH values in the rhizosphere are important indicators that can lead to solid conclusions regarding the activity of plants and their conditions. In order to measure O_2 and CO_2 levels and pH values, these scientists had to use electrodes, inserting them into the relevant matter. However, the higher the precision of the measurement results required, the larger the number of measurements that had to be performed, both in terms of time and space. This, in turn, resulted in two very specific disadvantages: first of all, more measurements meant more time and money. Second of all, each invasive measurement brought with it the risk that measurement results would be altered by the measuring method itself. In addition, the conventional measuring methods being used at the time could not reproduce the heterogeneity of a natural plant environment (soil, roots, composition), and only yielded mainly static tables with numerical results, instead of dynamic visual representations.

Measuring Equipment

Against this background, Blossfeld decided to look for new avenues in non-invasive (i. e., non-contact) chemical analysis, a process during which both his doctoral advisor, Professor Dr. Rainer Lösch (Head of the Geobotany Department at the School of Mathematics and Natural Science at the University of Düsseldorf at the time), and Assistant Dr. Dirk Gansert (formerly a research assistant at Dr. Lösch's department, now coordinator of the Göttinger Center for Biodiversity Research and Ecology at the University of Göttingen) would provide important support. Dr. Gansert had good contacts at PreSens and was already a firm believer in the advantages of non-invasive measuring methods as a result of his involvement in other projects. The people at PreSens found the challenge extremely interesting and developed the required measuring equipment (optical unit and optodes).

Semi-Nature in a Rhizobox

A semi-natural system was then created in what is known as a rhizobox. This system was designed with growth conditions (for plants) that were extremely close to those found in nature, especially in terms of substrates, water supply, and nutrient supply. The plants in the rhizobox were placed in such a way that their roots grew directly along the box´s front Plexiglas pane. A sensor film (optode) was placed between the pane and the root system as the counterpart to an optical signal sensor (glass fiber) in such a way that its entire area was in direct contact with the soil and the roots on one side and with the pane glass on the other. A special device with stepper motors was designed for automatically positioning the glass fiber intended to transfer the measured signal between the optode and the detector. Various standard programs were used to control measurements and display the saved measurement data. The stepped motor system moved the glass fiber´s end from outside along the rhizo-box pane in the X-axis and Y-axis directions in front of the sensor film. The combination between this stepper motor system and PreSens´ measuring technology would prove to be really effective throughout the entire experiment.

Fascinating Results

Just as an example, this method made it possible to perform 1.1 million pH value measurements in an automated manner during a period of approximately eight weeks (300 measurements every 20 minutes). In other words, no manual intervention or corrections of any kind were required once the test set-up was arranged. This ease of use was simply astounding for the biologists participating in the experiment, and the results obtained exceeded all expectations. For the first time ever, it was possible to observe and display the dynamic behavior of pH levels across a long period of time without the need for human intervention in bioprocesses. This made it possible to exclude any distortion in the results obtained that would be caused by experiment conditions, since, in contrast to conventional methods, the measuring instrument (the glass fiber) did not have to be inserted into the matter to be analyzed (except for the sensor film, which of course was placed inside the soil). For all intents and purposes, measured values were read by the sensor film in the rhizobox and were then relayed optically to the glass fiber through the pane. The analysis software used in Dr. Blossfeld´s experiment analyzed and prepared the measured data graphically after this.

A New Dimension

Another unique aspect of this new method was the fact that measurements were not just assigned to time series in columns of numbers, but could also be displayed in a manner that reflected real-life conditions with complete accuracy. Graphic animations were used to display measured value changes in real-time, and the resulting visual representations could be played forward and backward (and sped up or slowed down in both directions) in a continuously variable manner. In other words: long-term series of measurements no longer had to be taken with countless expensive, time-consuming, individual manual measurements. Instead, they could now be carried out in a fully automated manner - even "on the side" while researchers spent their time on other activities. After a short processing time, results were available at incredibly high resolution levels and could be analyzed in fast motion by means of animation.

Experts Show Enormous Interest

After its publication in journals such as "Plant and Soil" and "Plant, Cell & Environment", Dr. Blossfeld´s new method met with an outstandingly positive response in professional circles. At congresses in Sacramento, Leipzig, and Turin; during his postdoctoral stint at the University of Nancy (INPL (ENSAIA) / INRA Laboratoire Sols et Environnement); and after his presentation at the INRA Research Center in Montpellier (Unité Mixte de Recherche "Rhizosphere & Symbiose") - wherever he presented the new measuring method, interest soon followed. Today, Dr. Blossfeld´s method is already being used in many places, both with and without a servo motor system. The latter is currently being mass-produced (by Dipl.-Ing. Müller, Düsseldorf), and Dr. Blossfeld considers the use of PreSens optodes to be the decisive advantage in the system used for his measuring method.

First Industrial Application

Dr. Blossfeld´s new measuring method also raised eyebrows in industrial circles, and the biologist has already been able to use it in this area with tremendous success, as the case of American fertilizer producer AGROTAIN shows. AGROTAIN produces pelletized urea nitrogen fertilizers, to which an enzyme inhibitor is added. This enzyme inhibitor ensures that nitrogen applied to fields can be used to its full extent by plants and is not lost due to volatilization. An important advantage, given that 20 - 60 % of nitrogen in non-treated fertilizers can be lost in the form of ammonia released into the air, depending on how acid or alkaline the corresponding soil is (pH value). Soils and fertilizer applications with and without the enzyme inhibitor were compared during tests, and, with his new method, Dr. Blossfeld was able to accurately reproduce the dynamic behavior of pH values in the samples and demonstrate the effectiveness of AGROTAIN´s enzyme inhibitor. The speed at which untreated fertilizer converted into ammonia was absolutely surprising, as was the fact that the degradation process could be followed directly through the changes in measured values obtained with Dr. Blossfeld´s method.

Countless Possibilities

With his new measuring method, which allows for the lifelike reproduction of dynamic pH, O_2, and CO_2 behavior in soil, Dr. Blossfeld has taken an important step forward that will enable completely new research approaches and projects in the future. The researcher is thoroughly pleased with this result, as well as with the great interest that the international professional community has shown during the last few years, and sees enormous potential for both science and industry as his method is applied increasingly worldwide.