

Development of an ISFET-based analysis microsystem for nitrogen cycle monitoring in durum wheat crop

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Introduction:

Environmental impacts of excessive use of fertilizers entail the need for assessing the soil spatial nitrogen variability. Conventional soil sampling methods are expensive, time consuming and do not permit nutrients levels to be tracked spatially and over time. Thus, this project aims to develop a wireless sensors network (WSN) based on pH, pNH₄ and pNO₃ ion-sensitive field effect transistor (ISFET) to provide a low-cost, robust and real-time management tool for farmers.

Methods:

pH-ISFET microsensors were fabricated using silicon technology with a silicon nitride pH-sensitive layer. The latter were then adapted to the nitrate and ammonium detection by casting an ion-sensitive membrane consisting of fluoropolysiloxane and specific ionophores (nonactin and tridodecylmethylammonium nitrate for NH₄⁺ and NO₃⁻ ions, respectively). Analyses of pH-ISFET were conducted in soils samples and compared to the results given by standard laboratory methods while pNH₄ and pNO₃-ISFET were characterized in solutions with ammonium nitrate concentrations ranging from 10⁻⁶ to 10⁻¹ M.

Results:

We first demonstrated the detection capability of pH-ISFET right from 30% of maximum soil water holding capacity which is far below typical water contents during wheat growth. Then, the in-situ pH-measurements in acid and basic soils showed a maximum error of only 0.6 pH unit. Considering using ISFET during all wheat growth stages, pH-ISFET displayed a small potential drift of 18 mV (equivalent to 0.35 pH unit) after two months of in-situ recording. Finally, functionalized ISFET exhibited sensitivity of around 35 mV/pNH₄ and 55 mV/pNO₃, respectively, and detection limit around 10⁻⁴ M, in accordance with standard values in field conditions.

Conclusions:

This study showed that ISFET sensors are suitable for a long-term analysis of soil nutrients and, once nitrogen-functionalized ISFET properties will be validated in soil, this system could help growers to reduce the environmental footprint.