ISE-based Embedded System for Hydroponic and Soil Nutrient Monitoring

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Introduction

Nowadays, there has been a high need for recirculating hydroponic solutions used in greenhouses to reduce the environmental impact of soil and water pollution induced by the used nutrient solutions. Efficient monitoring of nutrients in soil and hydroponic solutions, using real-time, on-site methods, could allow accurate estimation of required rates for variable-rate fertilizer application in agricultural fields and greenhouses. The objectives of this study were 1) to conduct a validation test of using a laboratory-made on-site hydroponic nutrient monitoring system for simultaneous measurement of NO$_3$ K, and Ca ions in hydroponic solutions, and 2) to evaluate the capabilities of cobalt rod-based P electrodes in hydroponic and soil extracting solutions with respect to their sensitivity responses.

Materials and Methods

For the measurement of NO$_3$ K, and Ca ions in solutions based ISEs, PVC membranes with a diameter of 2.5 mm were attached to plastic electrode bodies, and were filled with 0.01M NaNO$_3$ + 0.01M NaCl, 0.01M KCl, and 0.01M CaCl$_2$ as an internal solution, respectively.

For sensing phosphorus, 99.95% purity of cobalt rods were attached to plastic electrode bodies using soldering and silicone gel.

A prototype of an ISE-based embedded system mainly consisted of a combination of six N, K, and Ca ISEs (two of each), a double-junction reference electrode, a solution container, a sampling system using three pumps and solenoid valves, a signal processing circuit, and an Arduino board for data acquisition and system control.

Results and Discussion

There were highly linear relationships between the concentrations of NO$_3$ K and determined by the embedded system and standard analyzers, with slopes close to unity and high coefficient of determination ($R^2$) of 0.99. However, Ca ISE underestimation by 96% with a relatively low $R^2$ of 0.84, implying that the Ca ionophore II would not be suitable for sensing the Ca ion.

Conclusions

When using the developed ISE-based embedded system, the predictive capability of the NO$_3$ K and Ca ISEs in hydroponic solutions were satisfactory. However, the use of Ca ionophore II was not suitable for measuring Ca ion. In soil extracts, the responses of the cobalt electrodes in Bray P$_2$ were considerably reduced at the phosphate concentration range of $< 10^{-2}$ M whereas the responses were better in Kelowna solution.

Future work will attempt to enhance the sensitivity of the Ca ISE by using new material as a Ca ionophore as well as to investigate the applicability of using cobalt electrodes for sensing phosphate in Kelowna-based soil extracts obtained from Korean soils.