

The 11th Asian-Australasian Conference on Precision Agriculture (ACPA 11)  
October 14-16, 2025, Chiayi, Taiwan

## FIELD TESTING OF A LABORATORY-MADE PORTABLE HYDROPONIC NUTRIENT ANALYZER WITH ION-SELECTIVE ELECTRODES

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### ABSTRACT

As a strategy to address climate change and declining agricultural productivity, hydroponic systems have gained increasing attention. In particular, precise control of nutrient ion composition in nutrient solutions is essential for ensuring stable crop growth and improving product quality. However, most hydroponic farms currently rely on pH and electrical conductivity (EC) sensors for nutrient solution management. While EC reflects the overall ionic strength, it does not provide quantitative information on individual ions such as nitrate ( $\text{NO}_3^-$ ) and potassium ( $\text{K}^+$ ), which are critical for plant nutrition. In this study, we developed a portable ion monitoring system with improved circuit design and signal processing technology, capable of providing real-time and on-site nutrient monitoring for hydroponic farmers. To enable stable measurement of ion-selective electrodes (ISEs) with high internal impedance, a mechanical relay-based multi-selector circuit was implemented. Power line noise at 60 Hz was effectively suppressed by applying a low-pass filter after signal amplification, and a bias voltage issue—caused during non-measurement periods—was resolved by removing a 3 M $\Omega$  resistor in the circuit. In principle, the proposed system measures the electromotive force (EMF) of nitrate and potassium ISEs, and quantitatively estimates ion concentrations in drainage samples based on the established relationship between EMF and ion concentration. The system was tested in several greenhouses owned by farmers, and its performance was validated by comparing the results with data obtained from a standard testing laboratory.

**Keywords:** Ion-selective electrode (ISE), Nutrient solution monitoring, Hydroponics, Real-time sensing

### INTRODUCTION

Hydroponics requires precise nutrient monitoring. Although ion-selective electrodes (ISEs) can measure individual ion concentrations, their field use is limited by high impedance and signal

cross-talk. To address this, we developed a portable monitoring system with a relay-based multiplexer, low-pass filter, and bias voltage correction

## MATERIALS AND METHODS

### ISE Sensor Array and Portable Measurement System

PVC-based nitrate-selective membranes were prepared using TDDA and NPOE (Jung et al., 2015). The portable system included a relay-based channel selector, a low-pass filter, and bias voltage correction. The ISE array was tested in Yamazaki nutrient solution, with 10 mL of 0.1 M NaOH or 0.1 M HNO<sub>3</sub> added to 100 mL of solution every 90s to observe stepwise concentration changes.

## RESULTS & DISCUSSION

The nitrate-selective electrode (NO<sub>3</sub><sup>-</sup> ISE) exhibited rapid response and stabilization within ~8 s to stepwise concentration changes from 243 to 992 ppm and down to 191 ppm. According to the Nernst equation, a 9% decrease in NO<sub>3</sub><sup>-</sup> concentration from 248 ppm to 225 ppm is expected to increase the EMF by 2.4 mV. Experimentally, the EMF increased by 6 mV, and the actual concentration change from 245 ppm to 223 ppm closely matched the theoretical prediction ( $\pm 1-3$  ppm), demonstrating that the signal processing board reliably captured and stabilized the EMF signals in response to nitrate variations.

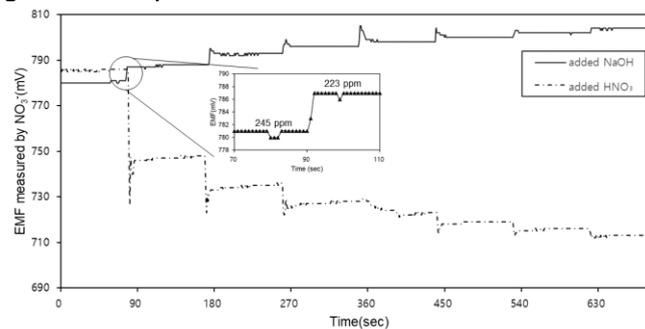


Fig.1 Stepwise EMF changes of the NO<sub>3</sub><sup>-</sup> ion-selective electrode in a Yamazaki solution with addition of 0.1 M NaOH (decreasing NO<sub>3</sub><sup>-</sup>) and 0.1 M HNO<sub>3</sub>(increasing NO<sub>3</sub><sup>-</sup>)

## CONCLUSIONS

The portable monitoring system reliably amplified and filtered EMF signals across varying nitrate concentrations, stabilizing within seconds, demonstrating its capability for accurate real-time monitoring of nitrate ions in hydroponic systems.

## ACKNOWLEDGEMENTS

This work was supported by the Korea Agriculture Technology Promotion Agency(KoAT) grant funded by the Korea government(RDA)(No. 2025-BA-02-014)

## REFERENCE

Jung, D.H., Kim, H.J., Choi, G.L., Ahn, T.I., Son, J.E., Sudduth, K.A. 2015. Automated lettuce nutrient solution management using an array of ion-selective electrodes. Transactions of the ASABE 58(5): 1309–1319.