

# Cost-Effective Modern Chemical Sensor System for Soil Macronutrients Analysis Applied to Thai Sustainable and Precision Agriculture

Sutasinee Apichai <sup>1,2,3</sup>, Thanawat Pattananandecha <sup>1,2,3</sup>, Kitti Phojuang <sup>2</sup>, Siraprapa Wattanakul <sup>2,4</sup>, Attachai Jintrawet <sup>2,5</sup>, Kanokwan Kiwfo <sup>2,3</sup>, Chalermpong Saenjum <sup>1,2,3,\*</sup>, and Kate Grudpan <sup>2,3,6</sup>

<sup>1</sup> Department of Pharmaceutical Science, Faculty of Pharmacy, Chiang Mai University, Chiang Mai, 50200, Thailand; sutasinee.apichai@gmail.com (S.A.); thanawat.pdech@gmail.com (T.P.); chalermpong.saenjum@gmail.com

<sup>2</sup> Center of Excellence for Innovation in Analytical Science and Technology (I-ANALY-S-T), Chiang Mai University, Chiang Mai, 50200, Thailand; phojuang.kitti@gmail.com (K.P.); siraprapa.wk@gmail.com (S.W.); k.kanokwan11@gmail.com (K.K.); kgrudpan@gmail.com (K.G.)

<sup>3</sup> Cluster of Excellence on Biodiversity-Based Economics and Society (B.BES-CMU), Chiang Mai University, Chiang Mai, 50200, Thailand

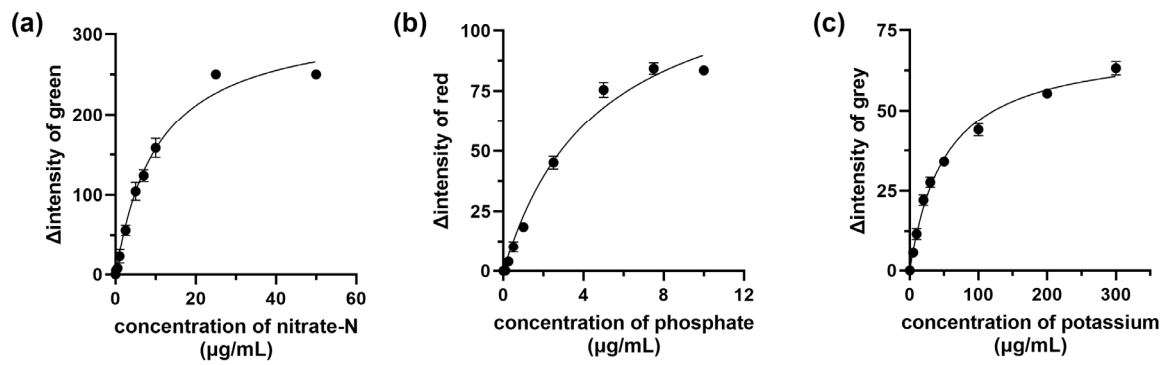
<sup>4</sup> College of Arts, Media and Technology, Chiang Mai University, Chiang Mai, 50200, Thailand

<sup>5</sup> Department of Plant Science and Natural Resources, Faculty of Agriculture, Chiang Mai University, Chiang Mai, 50200, Thailand

<sup>6</sup> Department of Chemistry, Faculty of Sciences, Chiang Mai University, Chiang Mai, 50200, Thailand

\* Correspondence: chalermpong.s@cmu.ac.th; Tel.: +66-89-950-4227

## Supplementary Materials

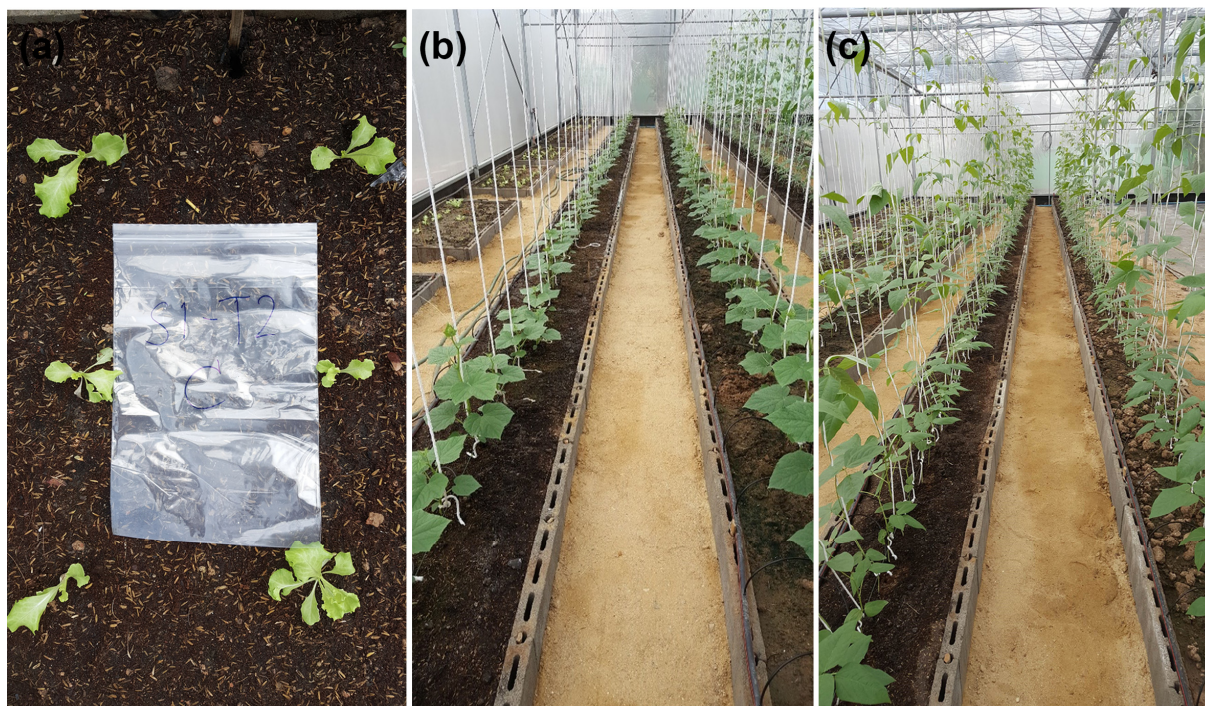


**Figure S1** Calibration curves for (a) nitrate-N, (b) phosphate, and (c) potassium based on color values. Error bars are standard deviations from triplicates.

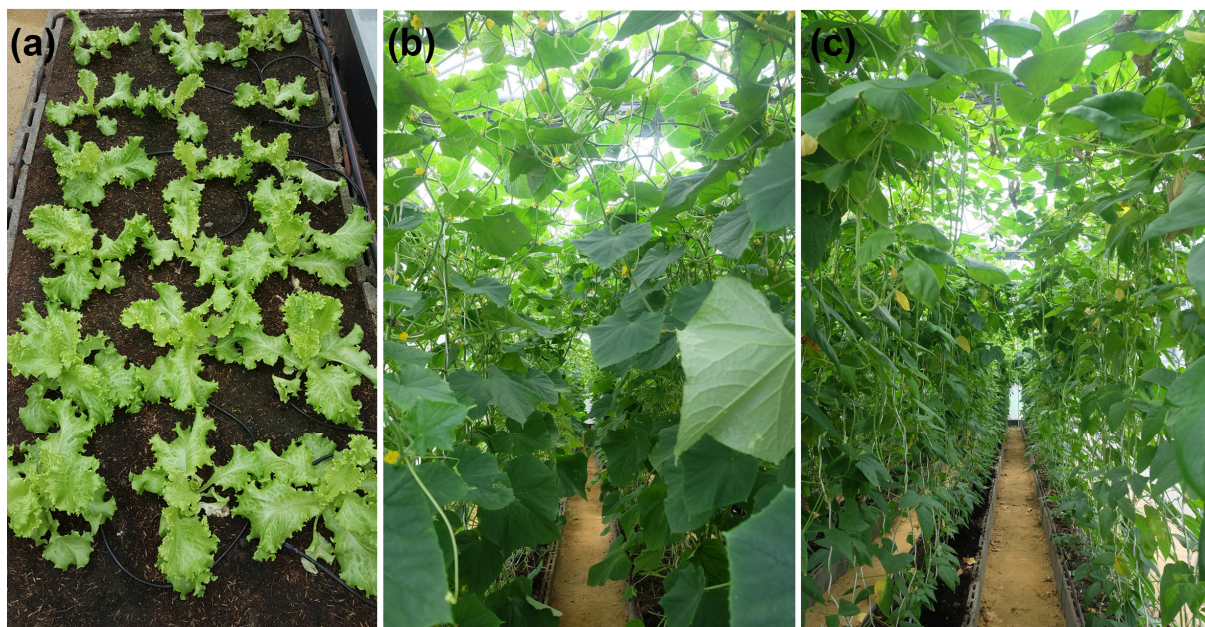


**Figure S2** Sampling soil samples while preparing the soil for plantation.

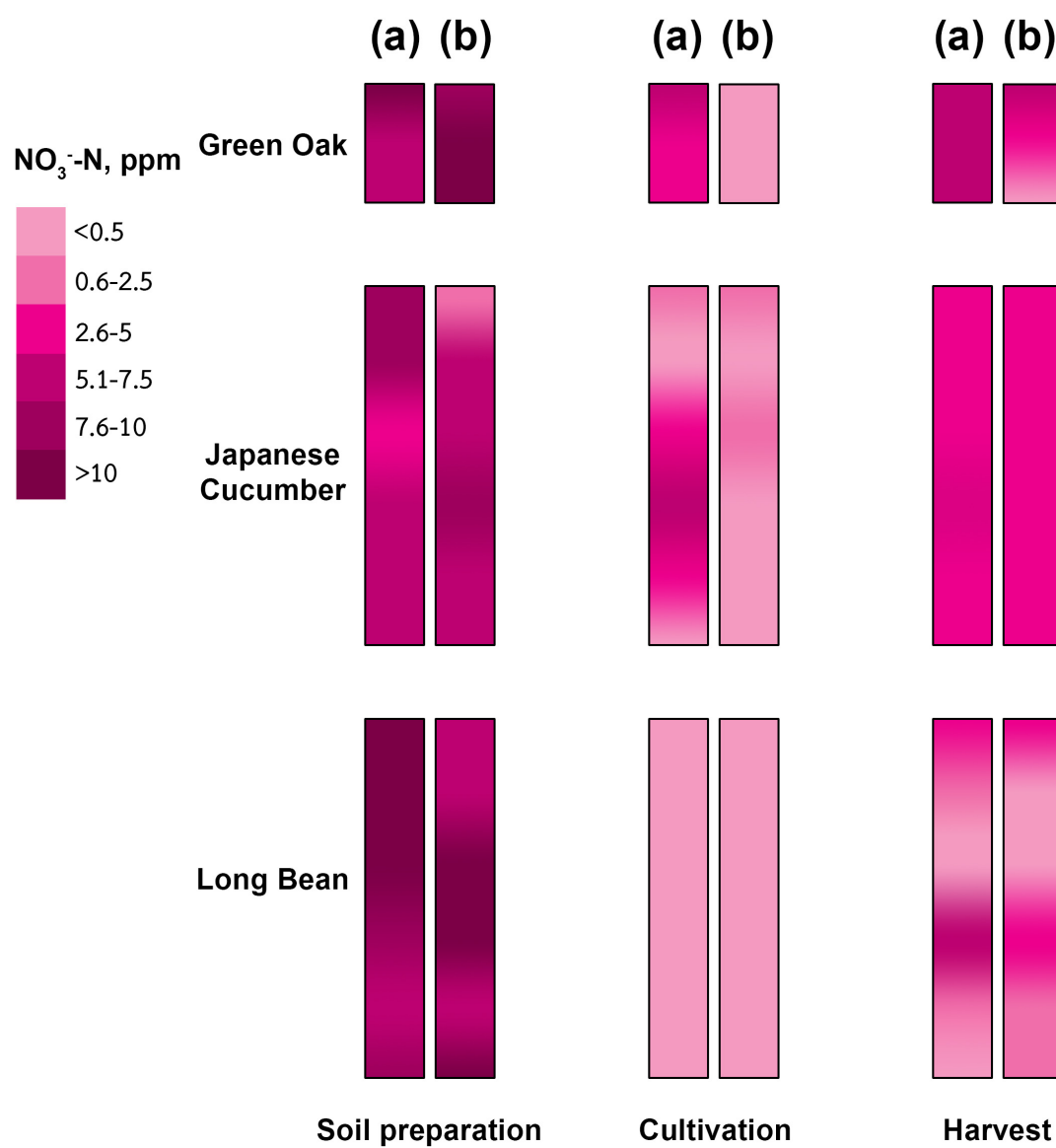




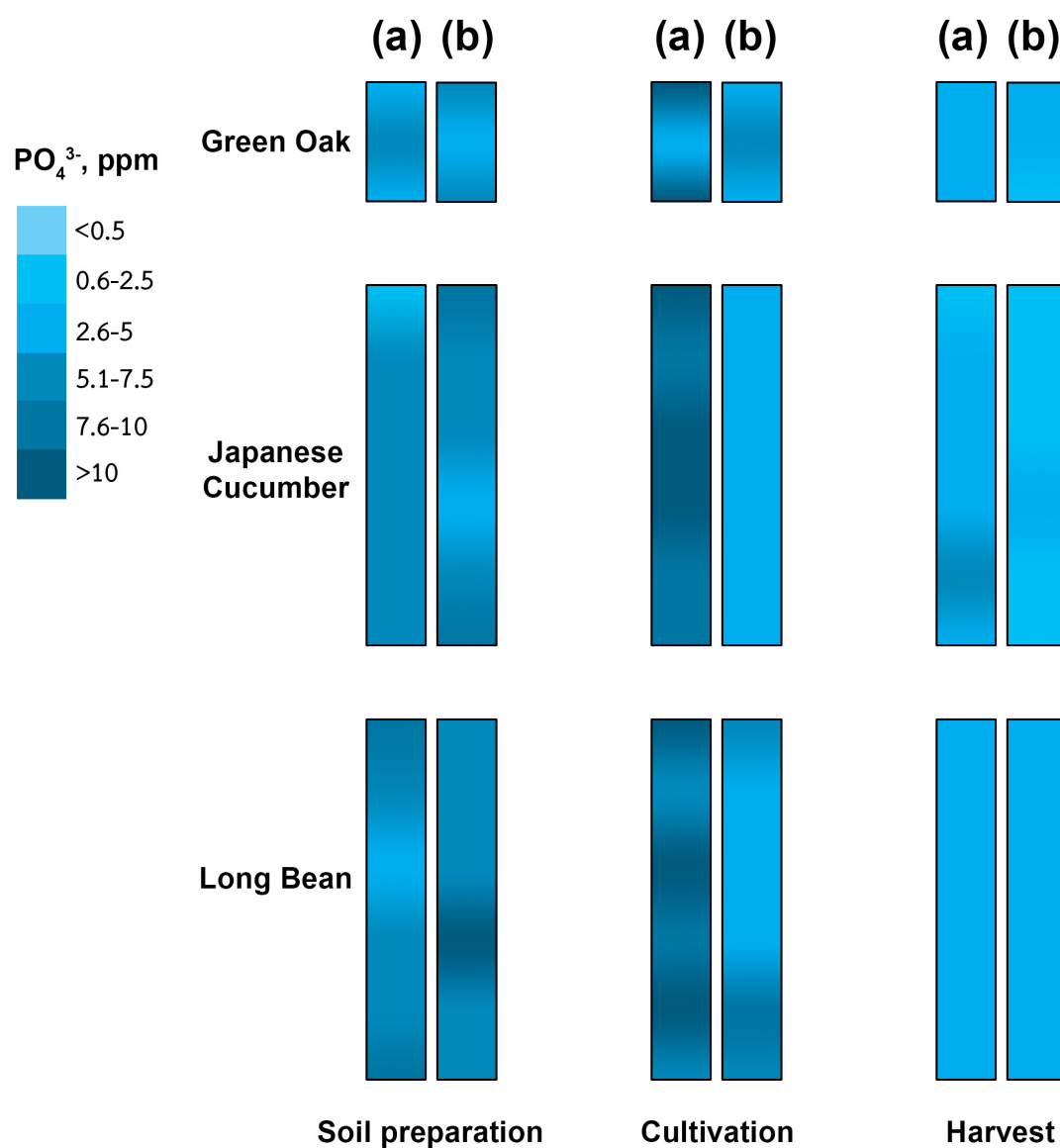
**Figure S3** Organic vegetables that include (a) Green Oak, (b) Japanese Cucumber, and (c) Long Bean about two weeks of growth.



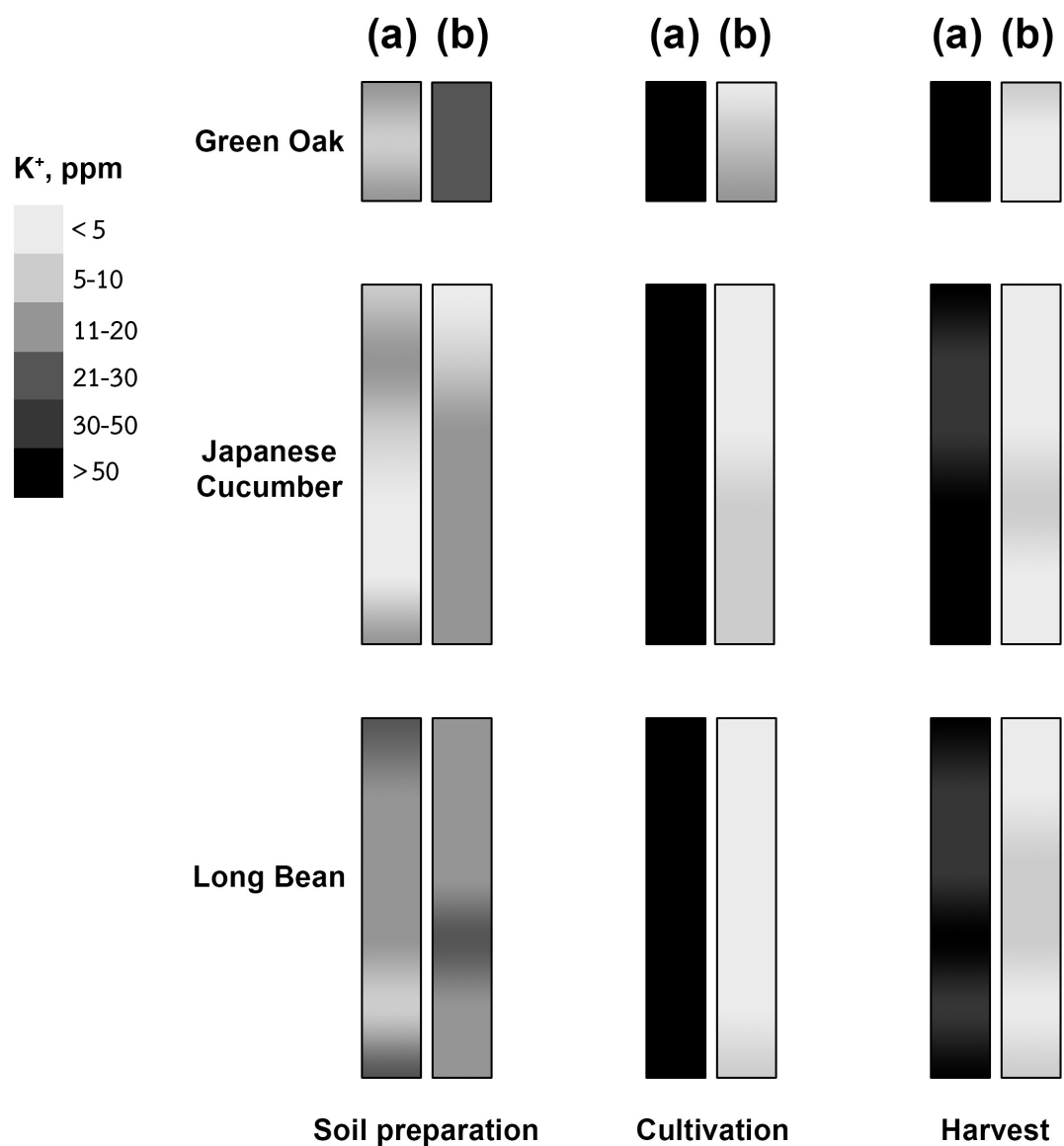
**Figure S4** Organic vegetables, which include (a) Green Oak, (b) Japanese Cucumber, and (c) Long Bean, were ready to harvest about four to six weeks of growth.



**Figure S5** The soil nitrate-N contents were obtained by the developed method in each growth period of organic vegetables. Comparison in nitrate-N content in soil between (a) manure treatment and (b) non-fertilizer.



**Figure S6** The soil phosphate contents were obtained by the developed method in each growth period of organic vegetables. Comparison in phosphate content in soil between (a) manure treatment and (b) non-fertilizer.



**Figure S7** The soil potassium contents were obtained by the developed method in each growth period of organic vegetables. Comparison in potassium content in soil between (a) manure treatment and (b) non-fertilizer.