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Application of Ultra Compact Element Analyzer for Soil Fertility Diagnosis of Agricultural Research in Southeast Asia

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***Abstract*— Soil analysis is quite an expensive option and thus it is not feasible for individual farmers, especially small farmers in Southeast Asia although it is imperative for appropriate soil fertility management in agriculture. Recently, Micro Emission Ltd. has developed a liquid electrode plasma method (LEP) and has successfully invented an ultra compact element analyzer or MH-5000. The purpose of this study is to evaluate the performance of MH-5000 in agricultural science by comparing it with the conventional ICP-AES method. Twenty soil samples from the Philippines, Lao PDR and Indonesia were measured by MH-5000 and ICP-AES to evaluate the performance of MH-5000. Results showed that a discrepancy was observed between the measured data by MH-5000 and the ICP-AES despite good fit by modified correlation coefficient (R^2). A compensate formula obtained through this correlation was able to revise the data by MH-5000 and this proved the adequate performance of the MH-5000 in designated analyses.**

***Keywords*—**agricultural R&D, portable apparatus, Southeast Asia

I. INTRODUCTION

It is essential to evaluate soil characteristics for agricultural production systems to design and implement appropriate fertility management and achieve better crop production. For better management, soil analysis plays a crucial role in providing details on soil physical and chemical properties. In general, soil is heterogeneous due to external soil-building factors such as soil flora, fauna, and climate [1] and thus an adequate number of soil samples is often required to obtain representativeness of analytical results from an agricultural land and this might lead to sample numbers becoming large. In addition, soil analysis requires an appropriate facility for accurate data collection and thus samples should be transferred from the field to the laboratory. On top of this, soil analysis is in general expensive due to the sophisticated equipment and high-quality reagents or gasses. All in all, soil analysis is quite an expensive option and thus it is not feasible for individual farmers, especially small farmers in Southeast Asia, to practice soil analysis to guide their soil fertility management.

The inductively coupled plasma atomic emission spectrometry (ICP-AES) is a key piece of equipment for the analysis of elements in soil, water, and plants. In the case of the ICPE-9000 (Shimadzu Corporation), it requires a certain space for the initial installation (ex. 3,000 mm x 1,000 mm), it consumes 12-20 L of argon gas per minute during analysis, and it incurs maintenance cost. Therefore, the cost per sample is high and this often limits the number of samples for analysis. On top of this, analysis by ICP-AES is mostly available in advanced research institutes that are located in economically developed areas or developed countries and thus this requires additional cost for transferring samples from the field to the laboratory. This means another cost and it is a time-consuming process due to some regulations that prohibit material transfer.

Recently, Micro Emission Ltd. (www.micro-emission.com) has developed a liquid electrode plasma method (LEP) that uses an electrically charged bubble by Joule heat to conduct AES [2,5,3]. Through this method, Micro Emission has successfully invented an ultra compact element analyzer that measures 204 mm (L) x 105 mm (W) x 114 mm (H) and weighs approximately 1.4 kg. This "ultra compact" analyzer uses only 6 AA batteries or an AC adapter, doesn't require argon gas, uses only 40 microliters of sample solution for measurements, and the equipment is almost maintenance-free (Micro Emission Ltd.).

This handy equipment has already been applied in some fields such as environmental science and pedology and a promising result was reported about its reliability in quantitative analysis [6].

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The purpose of this study is to evaluate the performance of the ultra compact element analyzer in agricultural science by comparing it with the conventional ICP-AES method and discuss the potential of this equipment for future application to agricultural research within the context of Southeast Asia.

II. MATERIALS AND METHODS

The commercial name of the ultra compact element analyzer is MH-5000 and its specifications are shown in Table 1. In order to evaluate its performance, we used exchangeable bases as a reference parameter to compare the results from the ICP-AES and MH-5000.

TABLE I
SPECIFICATION DETAILS OF THE MH-5000 (MICRO EMISSION LTD.)

Item	Specification details
Size	204 mm (L) x 105 mm (W) x 114 mm (H)
Weight	Approximately 1.4 kg (including batteries)
Power supply	Batteries (6 of AA size) or an AC adapter
Measurement time	Approximately 1 minute
Maximum number of measurements per time	Up to 6 elements (customized setting is required)
Measurement mode	4 modes
Display digits	2-3 digits
Detection limit	0.1-100 ppm (dependent on elements and samples)
Data saving	50 data points and latest spectrum

A. Soil Samples

The MH-5000 evaluated a total of 63 soil samples. Samples were collected from lowland rice fields in the Philippines, Indonesia, and Lao PDR (Fig. 1). Soil sampling was carried out at a depth of 0-20 cm and the soil was air-dried for 2 weeks prior to the analysis. All samples passed through a 2.0-mm-diameter sieve and were analyzed for exchangeable sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), and calcium (Ca^{2+}). Analysis was carried out in the analytical service laboratory (ASL) of the International Rice Research Institute.

B. Preparation of Solvent

Five grams of air-dried soil sample were extracted by 250 ml of 1N ammonium acetate (pH=7.0) [4] and Na^+, K^+, Mg^{2+}, and Ca^{2+} were measured by ICP-AES in the ASL to obtain a benchmark data set.

C. Measuring Conditions of the MH-5000

After the measurement of 63 samples by ICP-AES, 20 samples were selected from lower, middle and higher range according to the total value of 4 cations in order to proceed the measurement by MH-5000. Wave length was set at 589.0, 766.5, 518.4, and 422.7 nm for Na^+, K^+, Mg^{2+}, and Ca^{2+}, respectively. For measurements by the MH-5000, electrical conductivity should be adjusted within a specific range of 3.5 -30 S/m. However, all samples ranged far less than the range; therefore, all samples were adjusted for electrical conductivity by adding 0.01 ml of 60% nitric acid to 0.99 ml of solvent, which made the solvent 0.13 mol L^{-1} HNO_3. The setting for ignition was voltage of 750, with 2 milliseconds for on time and 40 miliseconds for off time.

D. Data Analysis

Results obtained from measurements with the MH-5000 were compared with the analytical results from the ICP-AES to obtain a fitting curve with an equation. Then, data from the MH-5000 were revised through an equation obtained to evaluate the performance of the MH-5000. The evaluation was made by root mean square error (RMSE), which is often used to evaluate the error between benchmark and measured data:

$$RMSE = \sqrt{\sum_{i=1}^{n}}(X - xi)/n$$

where n is the total number of samples and X and xi are the data measured by the ICP-AES and MH-5000, respectively.

III. RESULTS AND DISCUSSION

Table 2 shows a summary of the analyzed data for the total of 63 soil samples from the Philippines, Indonesia, and Lao PDR. Results of soil analysis for these countries were represented in median, maximum value, and minimum value, respectively and the soils from Laos represented all parameters in exchangeable Na^+ and minimum and maximum value in other cations while the soils from the Philippines represented maximum value in exchangeable K^+, Mg^{2+}, Ca^{2+}. Soil texture in Laos and the Philippines is sandy loam and clay loam, respectively and the result of exchangeable cations coincided with the soil texture.

Twenty out of 63 samples underwent evaluation of the performance of the MH-5000 and data obtained were compared with the data from the ICP-AES (Fig.2). Graphs

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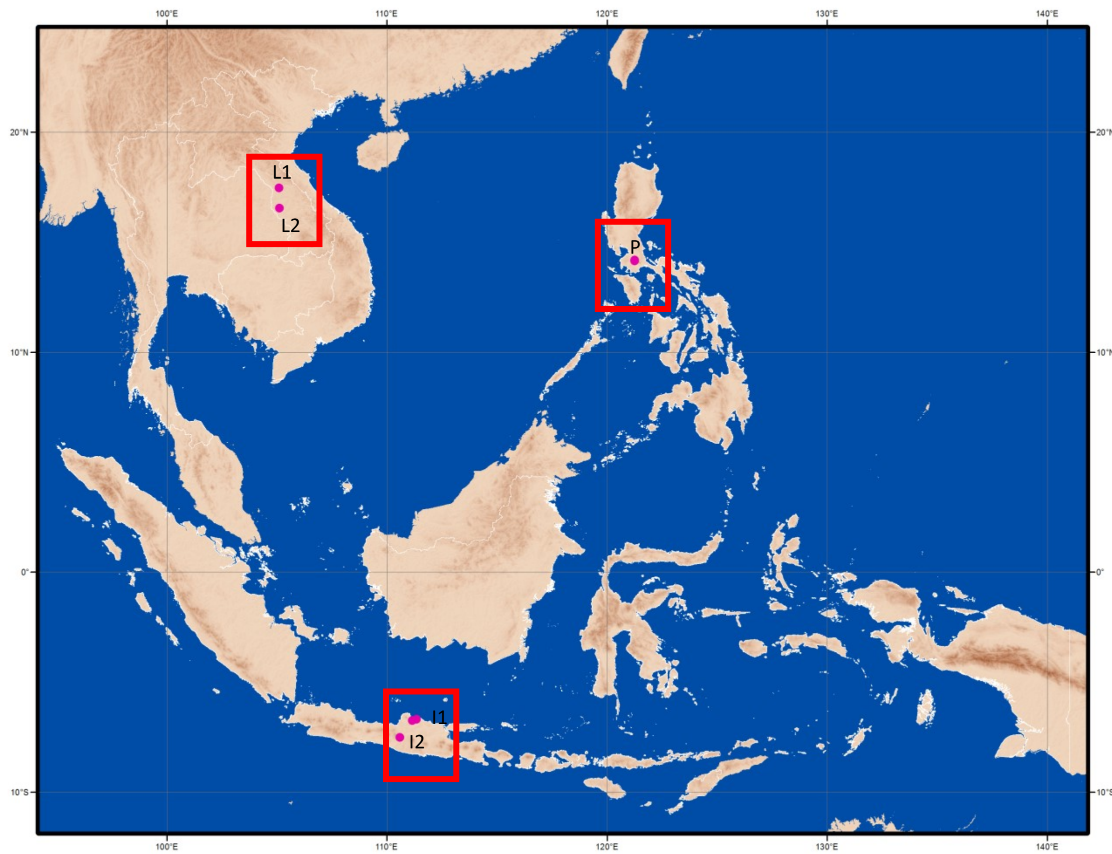

Figure 1 Location map of soil soil sampling sites in the Philippines (P:N14° 13', E121 15'), Lao PDR (L1:N16° 32', E105° 7', L2: N17° 27', E105° 5'), and Indonesia (I1: S6° 46', E111° 55', I2: S7° 21', E110° 42')

TABLE III
MEDIAN, MAXIMUM, AND MINIMUM VALUE OF SOIL SAMPLES FROM THE PHILIPPINES, INDONESIA, AND LAO PDR

n=63	Exch Na^+	Exch K^+	Exch Mg^{2+}	Exch Ca^{2+}
	$cmol_c\ kg^{-1}$			
Median	0.51	0.12	1.23	3.49
Max. value	3.49	1.37	13.20	24.00
Min. value	0.00	0.00	0.00	0.00
SD	0.86	0.49	4.37	8.39

showed that no critical discrepancy was observed between data from the MH-5000 and the ICP-AES. However, values from MH-5000 were larger than that from ICP-AES and the correlation was a quadratic. Nevertheless, the results showed a good fit correlation according to the obtained modified correlation coefficient (R^2) and this is adequate enough for a quantitative analysis in situ. Mg^{2+} showed the lowest R^2 among all cations because of the low fit around the lower range of less than 4 $cmol_c\ kg^{-1}$. A standard solution of Mg^{2+} didn't show an adequate difference in plasma intensity, which made the slope of the standard curve almost flat (data not shown).

Figure 3 shows the data plots of the MH-5000, which were revised by the equation obtained through Figure 2. A linear line shows a 1:1 line and the fit of the revised data was evaluated through RMSE. Data obtained show that the data for Na^+, K^+, and Ca^{2+} were fit around this 1:1 line and they showed a good fit according to the obtained RMSE, which was 0.33, 0.03, and 0.59 for Na^+, K^+, and Ca^{2+}, respectively. This result indicates that the reproducibility of the MH-5000 was adequate for analyzing designated cations with a standard methodology and this implies its application for agricultural research purposes. The RMSE of Mg^{2+} was higher than that of the other cations and this was due to the poor fit. Nevertheless, the RMSE obtained for $Mg^{2+}$was considered to be adequate enough in terms of reproducibility.

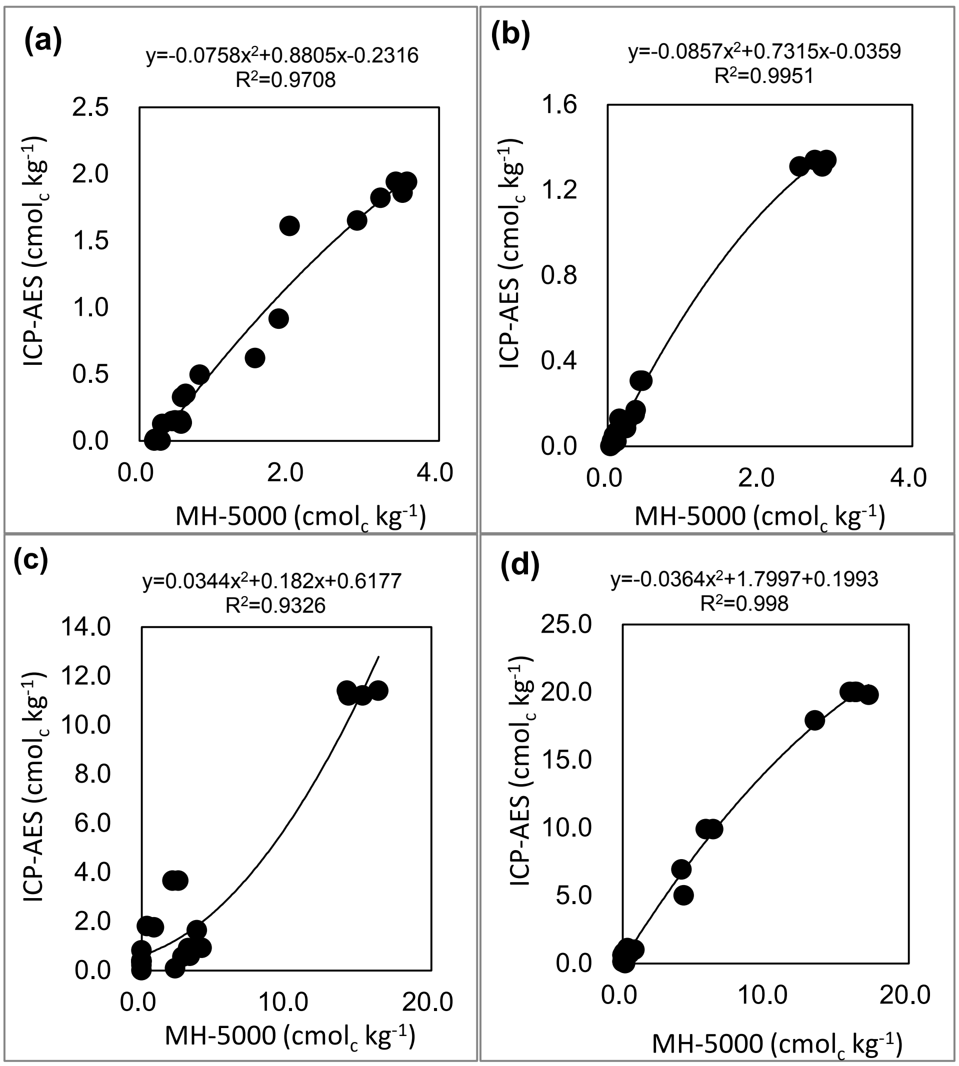

Figure 2 Exchangeable cations: (a) exch $Na^{+,}$ (b) exch K^+, (c) exch Mg^{2+}, and (d) exch Ca^{2+} measured by the MH-5000 (x axis) and ICP-AES (y axis)

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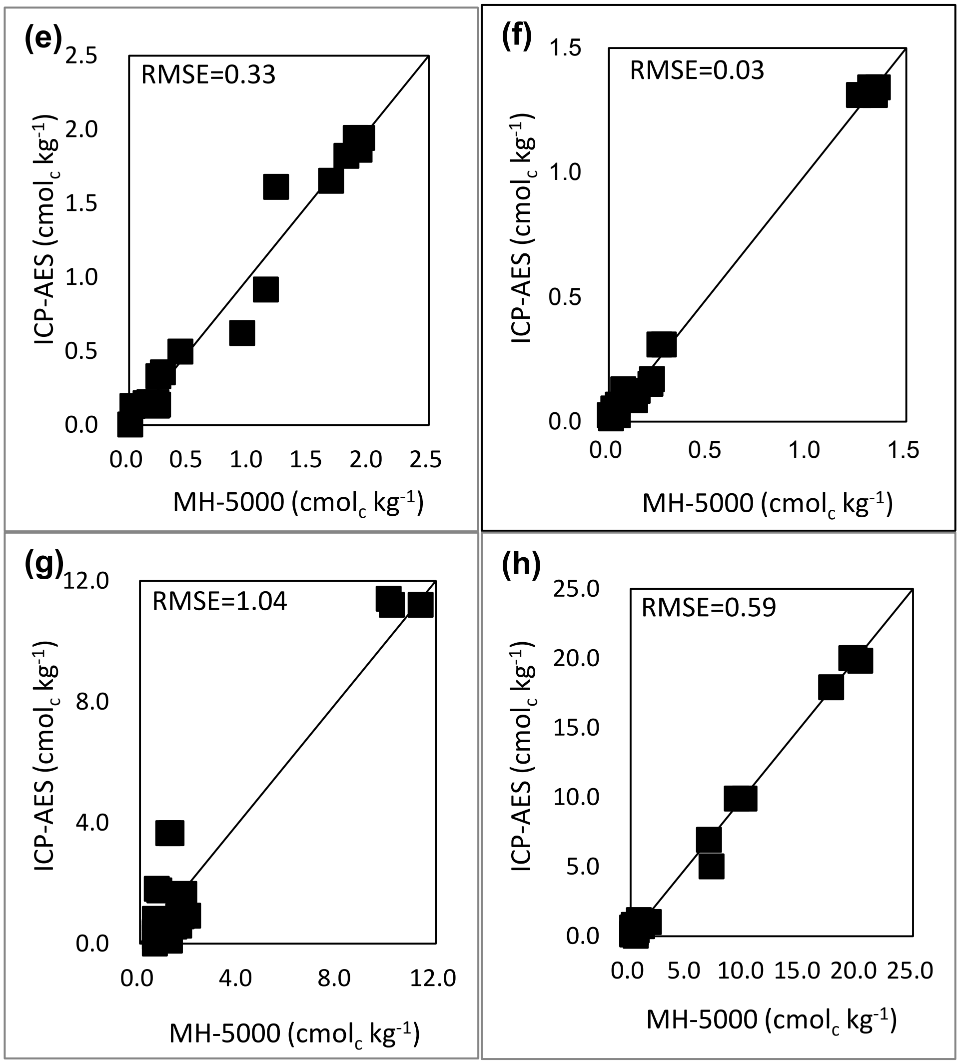

Figure 3 Revised data plot for (e) exch Na+, (f) exch K+, (g) exch Mg2+ and (h) exch Ca2+ measured by the MH-5000 (x axis) and ICP-AES (y axis)

IV. CONCLUSION

The results obtained showed that the data measured by the MH-5000 had relatively similar range to that of the data measured by the ICP-AES and showed a high correlation according to the R^2 obtained. Eventually, revision of the data measured by the MH-5000 was carried out with good results from RMSE and this proved the adequate performance of the MH-5000 in designated analyses.

Food production in Southeast Asia should be enhanced by adapting technology and soil analysis will play a vital role. Our results proved that the performance of the MH-5000 was almost the same as that of the ICP-AES and this could reduce the existing constraints in soil analysis for agricultural research by either reducing the cost of analysis or facilitating analysis without transferring samples to an advanced research institute. Our study was done on a

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limited number of samples and at a limited number of sampling sites. Further research should be carried out to test the performance of the MH-5000 at more sites and its performance on other elements such as phosphorous, zinc, manganese, copper, and arsenic.

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