



## Development of Quick Test Method for Soil pH, Nitrate, Phosphorus, and Potassium Combining Chemicals and Phone Cellular Application

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### ABSTRACT

Conventional soil analyses are time-consuming; therefore, the soil quick test (QT) method is needed. This study was to assess the accuracy of soil pH, N-nitrate, available phosphorus (P), and exchangeable potassium (K) analysis determined by the QT method developed by Akvo and calibrated with standard laboratory methods. The field research collected 131 soil samples, collected from horticultural lands in 4 regencies within East Java-Indonesia, started from February to August 2017. Soil analysis measured were soil pH, N-nitrate, available P, exchangeable K, textures, organic C, and CEC. The colorimetric-based QT method was performed on the soil sample extracted by Mehlich 1, and the color was developed by dipping strip test paper in supporting chemical solutions. A smartphone camera was used for the reading, and the results were directly displayed on the smartphone screen. The QT method's calibration models were created by stepwise multiple linear regression involving the correlated soil chemical properties. The values of calibrated QT method (i.e. soil pH, N-nitrate, and available P) showed significant correlations with the values from the laboratory. However, the results suggested that the QT method developed by Akvo could be used for nitrate due to having a relatively high correlation with that of standard laboratory.

### INTRODUCTION

The application of rapid and appropriate soil analysis technology is now attracting the attention of researchers. This matter is because conventional soil analyses are time-consuming and must be done in the soil laboratory. These situations are not comfortable for agriculture practitioners, so they need tools to assess their soil properties that are faster and practicable in the field.

One of the requirements of precision agriculture is soil analyses to establish fertilizer recommendations. Fertilizer recommendation is usually for nitrogen (N), phosphorus (P), and potassium (K). Inorganic fertilizers N, P, and K continuously at high doses result in nutrient imbalance and environmental pollution (Las, Subagyono, & Setiyanto, 2006). Nutrient imbalance can be

avoided if the fertilizer dosage refers to balanced fertilization based on soil nutrient analysis. Paddy soils in Java Island Indonesia are generally high in total P (Hartono et al., 2015; Wibowo et al., 2019). In the balanced fertilization period (1985-2000) and the location-specific nutrient management period (2000-2011) in Indonesia was an accumulation of P residues, so that rice plants were not responsive to P fertilizers (Darmawan et al., 2006). Even though the paddy soil has accumulated P residue, the farmers still provide TSP/SP-36 fertilizer. This case indicates that farmers put P fertilizer without soil analysis data, so they put P fertilizer regularly with the same amount. They follow the general fertilizer recommendation ignoring the soil properties. It generates general and uniform fertilizers advice across Indonesia. Fertilizer recommendations based on soil analyses can reduce the amount of fertilizer

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application and increase fertilizer use efficiency. Yost & Attanandana (2006) developed a site-specific K fertilizer recommendation for maize in Thailand, but getting data on K content in the soil was complicated.

One of Indonesia's problems is that farmers and extension workers cannot do soil analyses unless they send them to soil laboratories far from their homes. The location of soil laboratories is mainly in the cities, not in the villages. Furthermore, the number of soil laboratories in Indonesia is minimal. Procedures in laboratory analyses are complicated to follow by extension workers or farmers. Determination of nitrate in the laboratory (Black et al., 1965; Burt, 2004), and available P (Bray & Kurtz, 1945; Olsen, 1954) and also the determination of exchangeable K (Burt, 2004; Hajek, Adams, & Cope Jr., 1972; van Reeuwijk, 1993) are all relatively complicated. They need supporting apparatus to establish the analyses. For example, a spectrophotometer for the colorimetry method, atomic absorption spectrophotometer, or a flame photometer to measure the extracted ions. These apparatus are challenging to provide in the level of villages. Therefore it is necessary to produce Quick Test (QT) methods to accommodate those problems. Balai Penelitian Tanah (2007) has created a technology that can determine soil nutrient content through a quick test method of soil analysis using a dry soil test kit (*Perangkat Uji Tanah Kering* [PUTK]). PUTK is designed to measure P, K, organic C, pH, and lime requirements, except for N by colorimetric method. However, the working principle of PUTK in measuring soil P and K nutrients in the available form is still qualitative. Yost & Attanandana (2006) developed K fertilizer recommendation, but the requirements to reach the formula were complicated.

Akvo develops a QT method combining simple extraction using water for soil pH. The Mehlich 1 method (double-acid method) for N-nitrate, available P, and exchangeable K. Strip test paper is used by dipping it into the extracts and added by supporting solutions producing color. Phone cellular is used to scan the strip test paper and produce the values of those parameters. The application of phone cellular as color readers has been explored in agriculture to reduce the potential for human error in color detection (Golicz, Hallett, Sakrabani, & Ghosh, 2020; Han, Dong, Zhao, Jiao, & Lang, 2016; Intaravanne & Sumriddetchkajorn, 2015; Vesali, Omid, Kaleita, & Mobli, 2015).

However, the QT method produced by Akvo must be calibrated before it is widely used in Indonesia. The reference values are the values of soil parameters produced by conventional methods in the laboratory. The soil analysis results using the QT method are expected to correlate with soil analysis results in the laboratory closely. However, it should also be noted that other soil properties affect soil analysis results using the QT method. Therefore, the study's objectives were to correlate the values of pH, N-nitrate, available P, and exchangeable K of the Akvo QT method with those of the standard laboratory (Lab) method and calibrate the Akvo QT method using common Lab method values as a reference to find the best regression model.

## MATERIALS AND METHODS

The soil samples were collected from East Java (Jember, Banyuwangi, Malang, and Lumajang) from Februari-Maret and August 2017. The number of soil samples collected in Jember were 30, Banyuwangi 32, Malang 50, and Lumajang 19 samples (Fig. 1). The soil types varied and the soil orders were Inceptisols, Vertisols, and Ultisols. The land use in the location of the soil samples collected was horticultural land. Composite soil samples were collected within 0-30 cm depth in agricultural fields. Soil samples were treated according to the protocol of Akvo and Lab methods. The soil samples were air-dried, and their soil moisture was measured.

The tools used for QT analysis were a smartphone (Akvo Caddisfly Application installed), a set of Akvo Caddisfly tools (Fig. 2), Mehlich 1 solution (a mixture of 0.05 mol/l HCl and 0.0126 mol/l  $H_2SO_4$ ), and Aquadest.

As for pH measurement, 5.00 g of soil was weighed and put into a 50-ml centrifuge tube, and then 25.0 ml of aquadest was added. The 50-ml centrifuge was closed tightly and shaken quickly for about two minutes, and then it was let to stay for approximately ten minutes. After that, the liquid was sucked by syringe and filtered into the storage tube. The color paper was calibrated by using a Samsung J5 smartphone camera for soil pH analysis. A 5.00 ml of solution was taken from the filtered solution, and then the strip test was dipped for one second. Immediately it was pulled out, and then the strip test was put on the black area of the color chart, then it was measured by scanning it with a Samsung J5 camera. The results were displayed on the screen and stored in the smartphone.

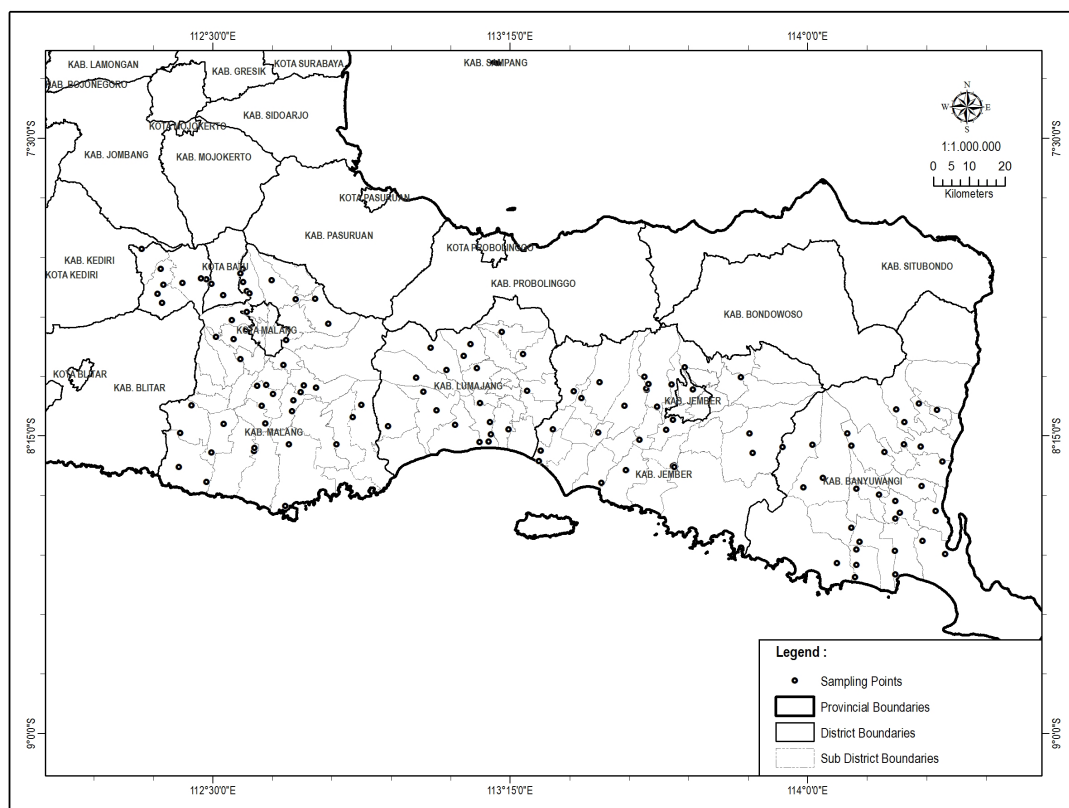


Fig. 1. The locations of the collected soil samples



Fig. 2. A set of quick test tools

**Table 1.** Parameters of soil analysis in the Lab and its analysis methods

No.	Soil Analysis Parameter	Analysis Method
1.	Soil pH	H <sub>2</sub> O 1:5 (van Reeuwijk, 1993)
2.	Nitrate	Spectrophotometer (Black et al., 1965; Burt, 2004; Widowati et al., 2011)
3.	Available P	Bray 1 (Bray & Kurtz, 1945)
4.	Exchangeable K	1 mol/l NH <sub>4</sub> OAc pH 7.0 (Burt, 2004; Hajek, Adams, & Cope Jr., 1972; van Reeuwijk, 1993)
5.	Organic C	Walkey and Black (Black et al., 1965; Graham, 1948; Rayment & Higginson, 1992)
6.	CEC	1 mol/l NH <sub>4</sub> OAc pH 7.0 (Burt, 2004; Hajek, Adams, & Cope Jr., 1972; van Reeuwijk, 1993)
7.	Soil texture (3 fraction)	Pipette (Sudjadi, Widjik, & Soleh, 1971)

As for nitrate measurement, 5.00 g of soil was weighed and put into a 50-ml centrifuge tube, and then 25 ml of Mehlich 1 was added. The 50-ml centrifuge was closed tightly, and it was shaken quickly for about two minutes, and then it was let to stay for approximately ten minutes. After that, the liquid was sucked by syringe and filtered into the storage tube. The color chart sheet was calibrated by using a Samsung J5 smartphone camera for soil nitrate analysis. A 2.00 ml of solution was taken from the filtered solution, and then the strip test was dipped for one second. Immediately it was pulled out, and then the strip test was put on the black area of the color chart sheet, then it was measured by scanning it with a Samsung J5 camera. The results were displayed on the screen and stored in the smartphone.

As for available P measurement, 5.00 g of soil was weighed and put into a 50-ml centrifuge tube, and then 25.0 ml of Mehlich 1 was added. The 50-ml centrifuge was closed tightly, and it was shaken quickly for about two minutes, and then it was let to stay for approximately ten minutes. After that, the liquid was sucked by syringe and filtered into the container tube. A 5 ml of solution was taken from the filtered solution, five drops of the material-1 solution were added, then stirred the sample evenly. Six drops of reaction material-2 were added into the smaller container tube. The color paper was calibrated by using a Samsung J5 smartphone camera for soil available P analysis. After that, the strip test was dipped in Mehlich 1 extract, added by reaction material-1 for 15 seconds, then pulled out and shaken. Then, the strip test was dropped in reaction material-2 for fifteen seconds, then pull out and nodded. Then, the strip test was put on the black area of the color chart sheet, and it was measured by scanning it with a Samsung J5

camera. The results were displayed on the screen and stored in the smartphone.

As for exchangeable K measurement, 5.00 g of soil was weighed and put into a 50-ml centrifuge tube, and then 25.0 ml of Mehlich 1 was added. The 50-ml centrifuge was closed tightly, and it was shaken quickly for about two minutes, and then it was let to stay for approximately ten minutes. After that, the liquid was sucked by syringe and filtered into the container tube. 5 ml of solution was taken from the filtered solution, ten drops of C-1 solution was added, then stirred the sample evenly. The color paper was calibrated by using a Samsung J5 smartphone camera for soil exchangeable K analysis. After that, the strip test was dipped in Mehlich 1 extract, which had been added by C-1 solution for one second, then pull out. Next, the K-1 reaction material was dropped on the strip test and left for 1 minute. Then, the strip test was put on the black area of color paper, and it was measured by scanning it with a Samsung J5 camera. The results were displayed on the screen and stored in the smartphone.

The parameters of soil analysis in Lab and its analysis methods were presented in Table 1. Measurement of soil pH in the Lab was determined by extracting the soil with water with the ratio of 1:5 and then shook for 30 minutes (van Reeuwijk, 1993). After that, the suspension was measured by a pH meter. N-nitrate of the soil samples was extracted by a solution containing 1 mol/l KCl and 0.1 mol/l HCl. Determination of their nitrate followed the method published by Widowati et al. (2011). The absorbance at 210 nm was determined and corrected by absorbance at 275 nm using a spectrophotometer (UV-1280, UV-VIS Spectrophotometer, Shimadzu Corporation, Japan). As for available P, it was obtained by Bray 1 method (Bray & Kurtz, 1945).

The cation exchange capacity (CEC) was obtained by extracting soil sample using 1 mol/l  $\text{NH}_4\text{OAc}$  pH 7.0 and the content of K was determined by flame photometer (Burt, 2004; Hajek, Adams, & Cope Jr., 1972; van Reeuwijk, 1993). Organic C was obtained by the Walkley and Black method (Graham, 1948; Rayment & Higginson, 1992) and soil textures was obtained by the pipets method (Sudjadi, Widjik, & Soleh, 1971).

The data from soil analysis using the Akvo Quick Test (QT) and the Lab results were used to construct a correlation between the QT method and soil analysis results in the Lab using the Pearson correlation test. The stepwise multiple regression was used to have model for predicting Lab results using the data of QT method. The equation is:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 \dots 1)$$

Where:

Y = results of soil analysis in the Lab (pH, N, P, K);  $b_0$  = intercept of the line on the Y-axis;  $b_1, b_2, b_3, b_4, b_5, b_6$  = regression coefficient; X1 = results of soil analysis using QT method (pH, N, P, K); X2 = organic-C; X3 = CEC; X4 = sand; X5 = silt; X6 = clay.

The model was expected to be close to the results of soil analysis obtained from the Lab by analysing their correlations.

## RESULTS AND DISCUSSION

Fast and straightforward methods have several benefits, such as reducing the time needed, costs, skills, types of equipment, chemicals, and others. Besides, it also provided more help for farmers to conduct soil testing without waiting for a long time to have N, P, and K soil data before planting. These were allowing them to apply the correct fertilizer rate (Koralage, Weerasinghe, Silva, & De Silva, 2015). The QT method developed by Akvo was expected to meet these expectations. The use of smartphones developed by Akvo to measure nutrient levels in the soil can be used as a substitute for a reflectometer, thus saving costs while reducing the potential for human error in color detection (Golicz, Hallett, Sakrabani, & Ghosh, 2020). The results of measuring soil nutrients using Akvo are quantitative. The Indonesian Soil Research Institute developed the Dry Soil Test Kit (PUTK) to directly calculate P, K, organic C, pH, and lime requirements directly in the field using the colorimetric method. The results were still qualitative (Balai Penelitian Tanah, 2007) and are relatively subjective in

detecting color. Yamin *et al.* (2020) using only water extractor and not integrated to phone cellulars to detect color to determined macronutrients in oil palm plantation. Bamane *et al.* (2021) using a smartphone as a monitoring tool for rapid hexavalent chromium detection in water. Phone cellular technology has exciting opportunities to develop low-cost decision support tools in agriculture, and it can be explored more in the future.

### Correlation Analysis between Soil Analysis Results (pH, N-nitrate, Available P, and Exchangeable K) QT Method with the Results of Soil Analysis from the Lab

The QT method soil analysis results had a reasonably good correlation with soil analysis results from the Lab. Therefore, the first stage in this study was carried out correlation analysis to see the relationship between the soil analysis results of the QT method soil analysis results is from the Lab. Based on the study results, the correlations between pH, N-nitrate, available P, and the QT method with products from the Lab were low (Table 2). To determine the significance of the correlation coefficient ( $r$ ), then the calculated correlation coefficient value was compared with the  $r$  table with  $n = 131$  and  $\alpha = 5\%$ . From the  $r$  table, the  $r$  table is 0.172. The comparison of each of  $r$  value pH (0.257), N-nitrate (0.369), and exchangeable K (0.187) with  $r$  table (0.172) showed that the calculated  $r$ -value is greater than the  $r$  table. These showed that the pH, N-nitrate, and exchangeable K Akvo QT method were significantly correlated with soil analysis from the Lab method. As for N-nitrate, the correlation with the common laboratory method was very significant with  $\alpha = 1\%$ . However, these correlations were relatively low. A low correlation between QT and laboratory method, possibly because of some factors. For example,  $\text{K}^+$  extracted by  $\text{NH}_4\text{OAc}$  (ammonium acetate) pH 7 and determined by flame photometer was different from  $\text{K}^+$  extracted by mehlich and determined colorimetry in sensitivity (Eren *et al.*, 2014). Therefore, the results of pH, N-nitrate, available P, and exchangeable K analysis by QT must be calibrated.

Thus, soil analysis of the QT method needs improvements. This improvement could be made by calibrating the soil analysis of QT combined with other soil characteristics. Soil characteristics related to those parameters include soil texture, organic C, and CEC.

**Table 2.** Correlation between the results of soil analysis (pH, N-nitrate, available P and exchangeable K) Akvo QT method with the results of soil analysis from the Lab

Respons	r	n
pH	0.257*	131
N-Nitrate (ppm)	0.369**	131
Available P (ppm)	0.166	131
Exchangeable K (ppm)	0.187*	131

Remarks: \* = significant correlation with  $\alpha = 5\%$ ; \*\* = significant correlation with  $\alpha = 1\%$ .

**Multiple Linear Regression Analysis and Its Relationship with the Results of Soil Analysis (pH, N-nitrate, Available P, and Exchangeable K) of the Lab**

Multiple regression analysis in this study used the stepwise method. This method started by entering the independent variables (soil texture, organic C, and CEC) one by one gradually until the best regression model was obtained. The multiple linear regression models involving the results of the QT method (pH, N-nitrate, available P, and exchangeable K), organic C, CEC, and soil texture and the results of soil analysis from the Lab method (pH, N-nitrate, available P, and exchangeable K) were presented in Table 3.

**Correlation of Soil pH of Lab Method Results with Soil pH of Multiple Linear Regression Model**

Table 3 shows that the independent variables included in the Laboratory pH model were only the QT method's pH. The coefficient of determination ( $R^2$ ) is 0.068, meaning that this regression model influenced 6.8% of soil pH variability. The correlation between soil pH values of the laboratory and those resulting from the multiple linear regression model was 0.261 (Fig. 3). This correlation was relatively low, so QT for soil pH was not fitted to Lab soil pH.

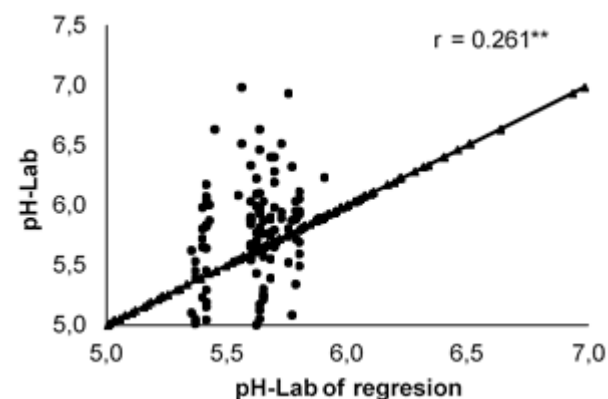
**Correlation between Soil N-nitrate of Lab Method with Soil Nitrate of the Multiple Linear Regression Model**

The independent variables included in the Laboratory N-nitrate model were CEC, organic C, N-nitrate of the QT results, and clay level (Table 3). Therefore, to get a more correlation to N-nitrate of the Lab results, a combination of CEC, organic C, and clay was needed. CEC had a negative correlation to N-nitrate from Lab, meaning that each increase of one unit of CEC reduced N-nitrate from Laboratory. A high CEC provides negative charges to prevent ammonium to move in the soil. Through the enzymatic oxidation process the ammonium is converted into nitrate quickly so that the conversion from ammonium into nitrate is more significant as more amount of N-nitrate is washed away (Mulyani, Suryadi, Dwiningsih, & Haryanto, 2001). Organic C and clay were positively correlated with the level of N-nitrate from Laboratory results, meaning that each increase in one unit of organic C and clay increased the level of nitrate of the Laboratory results. The higher the grade of organic C and clay in the soil, the higher the N-nitrate level in the soil. Organic matter's addition increased organic C in the soil. It increased the availability of nutrients in the soil, especially N. The clay content affected to increase the soil organic matter, which accelerated soil organic matter mineralization (Touré, Temgoua, Guenat, & Elberling, 2013). Therefore, the more clay the soil texture, the higher the N content in the soil.

The coefficient of determination ( $R^2$ ) of the multiple linear regression model to estimate nitrate from the laboratory was 0.416, which means that the regression model influenced 41.6% of soil nitrate variability of the Laboratory (Table 3). The correlation between the nitrate of the laboratory and nitrate of the multiple linear regression model was 0.645 (Fig. 4). This correlation value was better than that of nitrate before calibration (Table 2).

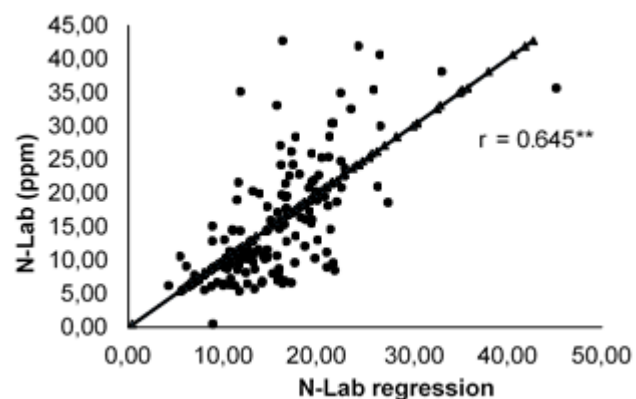
**Table 3.** Model of multiple linear regression analysis with stepwise method

Respons (Lab Analysis)	Model	R <sup>2</sup>	n
pH	$Y = 4.340 + 0.188 \text{ pH-QT}$	0.068	131
N-Nitrate (ppm)	$Y = 17.672 - 0.424 \text{ CEC} + 3.320 \text{ organic C} + 0.843 \text{ N-QT} + 0.080 \text{ clay}$	0.416	131
Available P (ppm)	$Y = 36.449 + 9.352 \text{ C-org} - 0.680 \text{ silt} + 0.195 \text{ P-QT}$	0.184	131
Exchangeable K (ppm)	$Y = 253.312 + 0.268 \text{ K-QT} + 5.183 \text{ CEC}$	0.064	131



Remarks: \*\* = significant correlation with  $\alpha = 1\%$

**Fig. 3.** Correlation between calibrated values of soil pH with the those of Lab



Remarks: \*\* = significant correlation with  $\alpha = 1\%$

**Fig. 4.** Correlation between calibrated values of N-nitrate with the those of Lab

In the past years, there were many substantial efforts to improve the simplification of nitrate soil tests. They applied rapid test methods such as colorimetric strip test (Jemison & Fox, 1988; Roth, Beegle, Fox, Toth, & Piekielek, 1991; Schaefer, 1986) that commonly used for soil, plant, or water nitrate analysis, but it was still semi-quantitative. Schmidhalter (2005) developed a rapid method for soil nitrate testing with reflectometry using the nitrate strip test (Reflectoquant® Nitrate Test, Cat No. 1.16995,0001, E. Merck, Darmstadt, Germany) and reflectometer (RQflex Reflectometer, Cat. No. 1.16970. 0001, E. Merck, Darmstadt, Germany). However, this method needed temperature correction during the measurement of nitrate. The rapid process of N-nitrate soil testing developed by Akvo Caddisfly is simpler, faster, and more accessible. It is based on an electronic device using the smartphone to identify the nitrate levels quickly.

This method is also used in nitrate determination using a nitrate test strip (AQUACHEK® nitrate test strips [ref. Number: 2745425]). However, the application system and its designation procedures still need to be improved.

#### **Correlation between Available P of Lab Method and Available P of Multiple Linear Regression Model**

Available P analysis in the Lab used the Bray 1 method (0.03 N  $\text{NH}_4\text{F}$  + 0.025 N HCl) because most of the land in East Java were acid (average pH 5.6), while the available P analysis in the QT method used Mehlich 1 extraction (0.05 M HCl and 0.0126 M  $\text{H}_2\text{SO}_4$ ). Table 2 showed that the correlation between the available P of QT results and Laboratory results was 0.166. Therefore, the correlation between the available P of the Bray 1 method (Bray 1 P) and the Mehlich 1 method was very low.

Based on Table 3, the multiple linear regression model's independent variables for available P were organic C and silt. Organic C was positively correlated, while silt content had a negative correlation with the available P-value. The higher the organic C, the higher the soil organic matter. The high organic content in mineral soil increased the availability of nutrients in the soil, including P. Conversely, the higher the silt content, the possibility to reduce the available P in the soil increased. The size of coarse silt particles makes the ability to absorb the nutrients was lower, or the nutrients were lost quickly due to leaching. The available P obtained by multiple linear regression model had a higher correlation (Fig. 5) with available P of Lab method than that of the QT method without calibration. However, the correlation obtained from the model was relatively low at 0.429 or  $R^2$  was 0.184, meaning that the regression model could explain the variability of Bray 1 P from Laboratory was 18.4%.

In comparison, the study of Sarker, Kashem, Osman, Hossain, & Ahmed (2014) showed that correlation of available-P using the Mehlich 3 method ( $0.2 \text{ N CH}_3\text{COOH} + 0.013 \text{ N HNO}_3 + 0.015 \text{ N NH}_4\text{F} + 0.25 \text{ N NH}_4 \text{NO}_3 + 0.001 \text{ M EDTA}$ ) with Bray 1 P had a determination coefficient of 0.948 or a correlation coefficient of 0.973. It means that the correlation between the Mehlich 3 method and Bray 1 was robust. The other study of Koralage, Weerasinghe, Silva, & De Silva (2015) found a fast and straightforward process in determining available-P, namely the Acetic Acid method, where 2.5% of the Acetic Acid solution was used as an extractor. The method's stages were similar to the procedure in the QT developed by Akvo with Mehlich

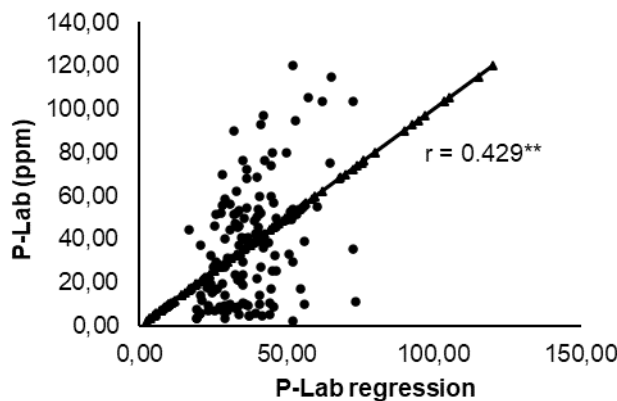
1 extraction. In the Acetic Acid method, the reading of available-P values was determined by a color chart where the colors consisted of three different blue colors. In contrast, the QT method developed by Akvo, the color was created by using QUANTOFIX® Phosphate test strips [ref. Number: 91320] and the smartphone read the result. In the study conducted by Koralage, Weerasinghe, Silva, & De Silva (2015), available P extracted by acetic acid correlated well with the Olsen method ( $r = 0.924$ ).

Therefore, the result suggested that QT developed by Akvo needs some improvements, some of them by trying some methods in extracting available P.

**Correlation of Exchangeable K of Lab with Exchangeable K of Multiple Linear Regression Model**

Table 3 shows that the independent variables included in the model obtained from multiple linear regression analysis for exchangeable K were CEC. CEC had a positive correlation, meaning that the higher the CEC, the higher the potassium content in the soil. CEC is the ability of the soil to adsorb and exchange cations, one of which was K.

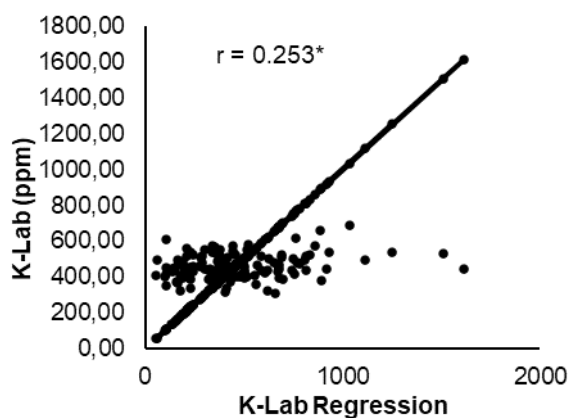
The K values obtained from the multiple linear regression model had a better correlation (Fig. 6) with that of the Lab than without calibration (Table 2). However, the model's correlation was very low at 0.253 ( $r$ ) or 0.064 ( $R^2$ ), meaning that the multiple linear regression model explained the variability of K values obtained from the Lab only 6.4%. Consequently, the method still needs improvement in the application system, determination procedures, and extracting solutions.



Remarks: \*\* = significant correlation with  $\alpha = 1\%$

**Fig. 5.** Correlation between calibrated values of available P with the those of Lab





Remarks: \* = significant correlation with  $\alpha = 5\%$

**Fig. 6.** Correlation between calibrated values of exchangeable K with the those of Lab

### CONCLUSION AND SUGGESTION

The soil analysis results (pH, N, P, and K) using the QT method had low correlations with the analysis results in the Lab. The accuracy of the QT results was relatively low. However, the multiple linear regression model involving other soil properties made the correlation values better than without calibration. The calibration models for QT method were that soil pH of Laboratory =  $4.340 + 0.188$  pH of QT ( $r = 0.261^{**}$ ), nitrate of Lab (mg/kg) =  $17.672 - 0.424$  CEC (cmol<sub>c</sub>/kg) +  $3.320$  organic C (%) +  $0.843$  nitrate of QT (ppm) +  $0.080$  clay (%) ( $r = 0.645^{**}$ ), available P of Lab (mg/kg) =  $36.449 + 9.352$  organic C (%) –  $0.680$  silt (%) +  $0.195$  P of QT ( $r = 0.429^{**}$ ) and exchangeable K of Lab (mg/kg) =  $253.312 + 0.268$  K of QT (mg/kg) +  $5.183$  CEC (cmol<sub>c</sub>/kg) ( $r = 0.253^*$ ). The results suggested that QT developed by Akvo could be used for nitrate due to having a relatively high correlation with that of the laboratory. QT for soil pH, available P, and exchangeable K needs some improvements due to having low correlations with those of the laboratory. Akvo is working on various methodologies and software improvements to improve that problem.

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### REFERENCES

Balai Penelitian Tanah. (2007). *Perangkat uji tanah kering V.01*. Bogor, ID: Balai Penelitian Tanah. Retrieved

from <https://balittanah.litbang.pertanian.go.id/ind/dokumentasi/leaflet/putk.pdf>

- Bamane, S. D., Bhojwani, V., Balkunde, P. L., Bhattacharya, M., Gupta, I., Mohapatra, A. K., ... Singh, A. (2021). Smartphone-enabled field monitoring tool for rapid hexavalent chromium detection in water. *Analytical and Bioanalytical Chemistry*, 413, 3455–3469. <https://doi.org/10.1007/s00216-021-03291-x>
- Black, C. A., Evans, D. D., White, J. L., Ensminger, L. E., Clark, F. E., & Dinauer, R. C. (1965). *Methods of soil analysis: Part 1. Physical and mineralogical properties, including statistics of measurement and sampling*. Madison, WI: American Society of Agronomy, Inc. <https://doi.org/10.2134/agronmonogr9.1>
- Bray, R. H., & Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil Science*, 59(1), 39–46. <https://doi.org/10.1097/00010694-194501000-00006>
- Burt, R. (2004). *Soil survey laboratory methods manual. Soil Survey Investigations Report No. 42 Version 4.0*. Lincoln, Nebraska: Soil Survey Investigations USDA-NRCS. Retrieved from [https://www.nrcs.usda.gov/Internet/FSE\\_DOCUMENTS/nrcseprd1026807.pdf](https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcseprd1026807.pdf)
- Darmawan, Kyuma, K., Saleh, A., Subagjo, H., Masunaga, T., & Wakatsuki, T. (2006). Effect of green revolution technology during the period 1970–2003 on sawah soil properties in Java, Indonesia: II. Changes in the chemical properties of soils. *Soil Science and Plant Nutrition*, 52(5), 645–653. <https://doi.org/10.1111/j.1747-0765.2006.00054.x>

- Eren, E., Öksüz, Y., Karadağ, S., Özen, S., Gemici, Z., & Kızılkaya, R. (2014). Investigation of a novel soil analysis method in agricultural areas of Çarşamba plain for fertilizer recommendation. *Eurasian Journal of Soil Science*, 3(2), 123–130. <https://doi.org/10.18393/ejss.24169>
- Golicz, K., Hallett, S., Sakrabani, R., & Ghosh, J. (2020). Adapting smartphone app used in water testing, for soil nutrient analysis. *Computers and Electronics in Agriculture*, 175, 105532. <https://doi.org/10.1016/j.compag.2020.105532>
- Graham, E. R. (1948). Determination of soil organic matter by means of a photoelectric colorimeter. *Soil Science*, 65(2), 181–184. Retrieved from [https://journals.lww.com/soilsci/Fulltext/1948/02000/DETERMINATION\\_OF\\_SOIL\\_ORGANIC\\_MATTER\\_BY\\_MEANS\\_OF\\_A.4.aspx](https://journals.lww.com/soilsci/Fulltext/1948/02000/DETERMINATION_OF_SOIL_ORGANIC_MATTER_BY_MEANS_OF_A.4.aspx)
- Hajek, B. F., Adams, F., & Cope Jr., J. T. (1972). Rapid determination of exchangeable bases, acidity, and base saturation for soil characterization. *Soil Science Society of America Journal*, 36(3), 436–438. <https://doi.org/10.2136/sssaj1972.03615995003600030021x>
- Han, P., Dong, D., Zhao, X., Jiao, L., & Lang, Y. (2016). A smartphone-based soil color sensor: For soil type classification. *Computers and Electronics in Agriculture*, 123, 232–241. <https://doi.org/10.1016/j.compag.2016.02.024>
- Hartono, A., Anwar, S., Satwoko, A., Koyama, K., Omoto, T., Nakao, A., & Yanai, J. (2015). Phosphorus fractions of paddy soils in Java, Indonesia. *Journal of International Society for Southeast Asian Agricultural Sciences*, 21(2), 20–30. Retrieved from [https://scholar.google.com/scholar\\_lookup?title=Phosphorus+fractions+of+paddy+soils+in+Java%2C+Indonesia&author=Hartono%2C+A.&publication\\_year=2015](https://scholar.google.com/scholar_lookup?title=Phosphorus+fractions+of+paddy+soils+in+Java%2C+Indonesia&author=Hartono%2C+A.&publication_year=2015)
- Intaravanne, Y., & Sumriddetchkajorn, S. (2015). Android-based rice leaf color analyzer for estimating the needed amount of nitrogen fertilizer. *Computers and Electronics in Agriculture*, 116, 228–233. <https://doi.org/10.1016/j.compag.2015.07.005>
- Jemison, J. M., & Fox, R. H. (1988). A quick-test procedure for soil and plant tissue nitrates using test strips and a hand-held reflectometer. *Communications in Soil Science and Plant Analysis*, 19(14), 1569–1582. <https://doi.org/10.1080/00103628809368035>
- Koralage, I. S. A., Weerasinghe, P., Silva, N. R. N., & De Silva, C. S. (2015). The determination of available phosphorus in soil: A quick and simple method. *OUSL Journal*, 8, 1–17. <https://doi.org/10.4038/ouslj.v8i0.7315>
- Las, I., Subagyo, K., & Setiyanto, A. P. (2006). Isu dan pengelolaan lingkungan dalam revitalisasi pertanian. *Jurnal Penelitian dan Pengembangan Pertanian*, 25(3), 173–193. Retrieved from <https://balittanah.litbang.pertanian.go.id/ind/dokumentasi/prosiding/mflp2006/irsal.pdf>
- Mulyani, N. S., Suryadi, M. E., Dwiningsih, S., & Haryanto. (2001). Dinamika hara nitrogen pada tanah sawah. *Jurnal Tanah dan Iklim*, 19(3), 14–25. Retrieved from <https://studylibid.com/doc/577898/dinamika-hara-nitrogen-pada-tanah-sawah>
- Olsen, S. R. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. Circular No. 939. Washington, DC: United States Department of Agriculture. Retrieved from [https://scholar.google.com/scholar\\_lookup?title=Estimation+of+available+phosphorus+in+soils+by+extraction+with+sodium+bicarbonate&author=Olsen%2C+Sterling+R.+%28Sterling+Robertson%29&publication\\_year=1954](https://scholar.google.com/scholar_lookup?title=Estimation+of+available+phosphorus+in+soils+by+extraction+with+sodium+bicarbonate&author=Olsen%2C+Sterling+R.+%28Sterling+Robertson%29&publication_year=1954)
- Rayment, G. E., & Higginson, F. R. (1992). *Australian laboratory handbook of soil and water chemical methods*. Inkata Press. Retrieved from <https://books.google.co.id/books?id=hwllAAAAAYAAJ>
- Roth, G. W., Beegle, D. B., Fox, R. H., Toth, J. D., & Piekielek, W. P. (1991). Development of a quicktest kit method to measure soil nitrate. *Communications in Soil Science and Plant Analysis*, 22(3–4), 191–200. <https://doi.org/10.1080/00103629109368406>
- Sarker, A., Kashem, M. A., Osman, K. T., Hossain, I., & Ahmed, F. (2014). Evaluation of available phosphorus by soil test methods in an acidic soil incubated with different levels of lime and phosphorus. *Open Journal of Soil Science*, 04(03), 103–108. <https://doi.org/10.4236/ojss.2014.43014>
- Schaefer, N. L. (1986). Evaluation of a hand held reflectometer for rapid quantitative determination of nitrate. *Communications in Soil Science and Plant Analysis*, 17(9), 937–951. <https://doi.org/10.1080/00103628609367764>
- Schmidhalter, U. (2005). Development of a quick on-farm test to determine nitrate levels in soil. *Journal of Plant Nutrition and Soil Science*, 168(4), 432–438. <https://doi.org/10.1002/jpln.200520521>
- Sudjadi, M., Widjik, S. I. M., & Soleh, M. (1971). *Penuntun analisa tanah*. Bogor, ID: Lembaga Penelitian

Arief Hartono *et al.*: *Quick Test Method for Soil Analysis* .....

- Tanah. Retrieved from [http://perpustakaan.kkp.go.id/union/index.php?p=show\\_detail&id=7070](http://perpustakaan.kkp.go.id/union/index.php?p=show_detail&id=7070)
- Touré, A., Temgoua, E., Guenat, C., & Elberling, B. (2013). Land use and soil texture effects on organic carbon change in dryland soils, Senegal. *Open Journal of Soil Science*, *04*(06), 253–262. <https://doi.org/10.4236/ojss.2013.46030>
- van Reeuwijk, L. P. (1993). *Procedures for soil analysis* (4th ed.). Madison, WI: International Soil Reference and Information Centre. Retrieved from <https://books.google.co.id/books?id=r6QdAQAAMAAJ>
- Vesali, F., Omid, M., Kaleita, A., & Mobli, H. (2015). Development of an android app to estimate chlorophyll content of corn leaves based on contact imaging. *Computers and Electronics in Agriculture*, *116*, 211–220. <https://doi.org/10.1016/j.compag.2015.06.012>
- Wibowo, H., Nalendra Warna, R., Wulandari, P., Prakoso, T., Prasetyo, D., Airlangga, T. A., ... Handayani, S. (2019). Identification the availability of P in land planted with corn on volcanic, karst and acid soils in Indonesia. *KnE Life Sciences*, *4*(11), 179–188. <https://doi.org/10.18502/cls.v4i11.3864>
- Widowati, L. R., De Neve, S., Sukristiyonubowo, Setyorini, D., Kasno, A., Sipahutar, I. A., & Sukristiyohastomo. (2011). Nitrogen balances and nitrogen use efficiency of intensive vegetable rotations in South East Asian tropical Andisols. *Nutrient Cycling in Agroecosystems*, *91*(2), 131. <https://doi.org/10.1007/s10705-011-9451-3>
- Yamin, M., bin Wan Ismail, W. I., bin Mohd Kassim, M. S., Binti Abd Aziz, S., Akbar, F. N., Shamshiri, R. R., ... Mahns, B. (2020). Modification of colorimetric method based digital soil test kit for determination of macronutrients in oil palm plantation. *International Journal of Agricultural and Biological Engineering*, *13*(4), 188–197. <https://doi.org/10.25165/j.ijabe.20201304.5694>
- Yost, R., & Attanandana, T. (2006). Predicting and testing site-specific potassium fertilization of maize in soils of the tropics - An example from Thailand. *Soil Science*, *171*(12), 968–980. Retrieved from [https://kukr2.lib.ku.ac.th/kukr\\_es/index.php/?/kukr/search\\_detail/result/340482](https://kukr2.lib.ku.ac.th/kukr_es/index.php/?/kukr/search_detail/result/340482)