Precision test for scanning of soil in durian orchard using near-infrared spectroscopy

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Abstract. Near infrared (NIR) spectroscopy is a rapid technique for non destructive testing. Durian is popular fruit in Thailand. Growing durian is not easy. It needs to provide proper nutrients. Therefore, this paper aims to test the repeatability and reproducibility of NIR scanning before conducting the feasibility test of creating the equation to predict the N P K value in the soil for the durian trees. Results showed that the repeatability of FT-NIR spectrometer and Micro-NIR spectrometer for fresh soil were 0.064 and 0.075, respectively and for soil powder, they were 0.039 and 0.048, respectively. The reproducibility of FT-NIR spectrometer and Micro-NIR spectrometer for fresh soil were 0.048 and 0.051, respectively and for soil powder were 0.051 and 0.046, respectively.

1. Introduction
Durian is a king of fruit in Thailand and favorite fruit of the world. The export of durian in Thailand has increased every year because Thai durian is preferred by the world market [1]. There are many varieties of durian. But the most popular is the Monthong variety. Durian has the scientific name as durio zibethinus murr. Durian flesh taste is sweet and the flesh texture is soft [2].

Durian fruit is a high price product. Therefore, farmers have to pay more attention in growing durian. But planting durian is not easy because durian requires high relative humidity and high temperature. If the moisture in the soil for the flowering and fruit setting season is not enough, it may cause the flowers and fruit to fall. Durian can grow in almost any soil, but need proper nutrient minerals. Farmers should provide nitrogen (N) Phosphorus (P) and Potassium (K) nutrients properly at each age [3].

N helps plant growth in the early stage, P enhances the growth of plants roots in the early stage of germination and K also promotes root growth [4].

In the analysis of N, P and K values in soil, there is a complicated and time-consuming process and need of chemical. Therefore, the NIR technique can reduce the process duration, because NIR is a fast predictive technique and without the use of chemical.

From the research of near infrared spectroscopy for determination of various physical, chemical and biochemical properties in Mediterranean soils [5], it was found that in creating a model for predicting total nitrogen in the soil, $r^2$ was 0.95, RMSECV was 0.41 g kg$^{-1}$ and RPD was 4.69. This model was constructed from 393 soil samples which scanned by Fourier-Transform near infrared (FT-NIR) spectrophotometer (MPA, Bruker Optik GmbH, Germany) at a wavelength of 12000-3800 cm$^{-1}$ by bringing 50 g of soil into a quartz glass in reflectance mode and rotating quartz glass for scanning. From the research of the soil structural quality using VIS-NIR spectra [6], a model for predicting total nitrogen in the soil provided $r^2$ of 0.93, RMSE of 0.04% and RPD of 4.13. For predicting potassium in soil, $r^2$ was 0.71, RMSE was 58.8 ppm and RPD was 2.03. The soil samples were from farms in Iceland scanned...
to obtain the spectra with VIS-NIR Systems 6500 (Foss NIRSystems, Denmark) at a wavelength of 400-2498 nm in reflectance mode. The predictions of nitrogen content in soil with NIR on real time [7] showed that a model for predicting total nitrogen with PLSR method, $r^2$ was 0.63, RMSEP was 0.056 mg kg$^{-1}$ and RPD was 1.838 and the predicting using SVM method, $r^2$ was 0.81, RMSEP was 0.053 mg kg$^{-1}$ and RPD was 2.129. The sample used in the experiment came from the apple orchard at the Beijing Xiang Tang Cultural Village. There were 90 specimens scanned by the FT-NIR spectrophotometer (MATRIX-I, Bruker corp., Germany) at a wavelength of 12493–3899 cm$^{-1}$. From the research of assessment of important soil properties related to Chinese soil taxonomy based on the VIS-NIR reflectance spectroscopy [8], the prediction model of total nitrogen, total potassium and total phosphorus by PLSR provided $r^2$ of 0.80, 0.61, 0.72, RMSE of 0.16, 0.19, 3.8 g kg$^{-1}$ and RPD of 2.25, 1.60, 1.68, respectively. The samples used in the experiment came from Zhejiang in the southeast of China and were scanned with Fieldspec® ProFR VIS-NIR spectrometer (Analytical Spectral Devices, Boulder, CO, USA). From the research of soil fertility assessment by VIS-NIR spectroscopy [9], the total potassium prediction model and Evaluation of soil model with MPLSR method provided $r^2$ of 0.623 and 0.878 respectively where the Foss-NIR Systems 6500 SY-II was used. The quantitative analysis of soil chemical properties with VIS/NIR diffuse reflectance spectrometry (ASD FieldSpec-II spectrometer, 0.4–2.5 μm) and partial least-square regression [10] reported a model, of predicting total potassium with PLSR method in which $r^2$ was 0.85 and RMSE was 0.47 g kg$^{-1}$. The spectral phosphorus mapping using diffuse reflectance of soils and grass [11] was investigated. It was found that in the modeling, the predicted total phosphorus by PLSR provided $r^2$ of 0.922 and RMSE of 273.3 mg kg$^{-1}$ and the predicted the total phosphorus model by MLR method provided $r^2$ of 0.883 and RMSE of 335.9 mg kg$^{-1}$.

According to the literature review, it is found that it is possible to use NIR spectroscopy to evaluate the nutrients in the soil. However, to begin the experiment it is still need to have a preliminary scanning precision test because each type of soil has different properties which has different scanning requirements,

Therefore the objective of this research was to test the possibility of scanning of soil with NIR in order to develop the model in the future by considering the repeatability and reproducibility of the scanning for the durian farm soil model. The repeatability will inform the precision of the scanning tool and the reproducibility will inform the consistency of the material that is measured. If the tool is precise and the material is uniform, it will make it possible for the model to be constructed with high accuracy.

2. Materials and Methods

2.1. Materials
Durian soil samples were from Monthong durian orchards in Rayong, Chanthaburi and Trad, Thailand. There were 3 samples from 3 different orchards. The samples were the fresh soil taken under the tree at a depth of 0-20 cm and 20-40 cm and the corresponding soil powder obtained from dried fresh soil, ground and sieved through 2 mm screen.

2.2. NIR scanning of the Soil
The soil samples were scanned by FT (Fourier transform)-NIR spectrometer (Bruker Ltd., Germany) and Micro-NIR spectrometer (Viavi, USA). Each sample was transferred into a quartz cup of 9.0 cm diameter and 9.0 cm height for full cup. For FT (Fourier transform)-NIR spectrometer, the sample scanned between wavenumber of 12,500 - 4000 cm$^{-1}$ (800 - 2500 nm) with a resolution of 16 cm$^{-1}$. The scanning was completed 32 times per one average spectrum. Before each sample scanning, the gold used as a reference material was scanned for background. For Micro-NIR, the sample was scanned in the wavelength range of 950-1600 nm and randomly scanned at 3 different positions around the bottom of quartz cup. All scanning was conducted at air conditioning room temperature (25.0 ± 2.0 °C).
2.3. Repeatability and Reproducibility Test

The repeatability of NIR scanning was determined by scanning on a sample at the same position for 10 times, then calculating the standard deviation (SD) value of the absorbance for the scanning. The 3 wavenumber from whole spectrum including 8163.2 cm\(^{-1}\) (1225 nm), 6896.6 cm\(^{-1}\) (1450 nm) and 6666.7 cm\(^{-1}\) (1500 nm) which were the vibration bands of CH, water and NH respectively were selected and the average SD of absorbance in all wavenumber were the repeatability of scanning of the instrument.

The reproducibility of NIR scanning was determined by scanning a sample for 10 times but re-load sample every time. The same 3 wavenumber as those used for calculate the repeatability were selected. and the average SD of absorbance in all wavenumber were the reproducibility of scanning of the instrument.

3. Results and Discussion

Figure 1 and 2 show the average spectra of soil samples both from fresh samples and powder samples. From figure 1, the peak of water is at 5145 cm\(^{-1}\) (1943 nm) for fresh sample. From figure 2, the peak of water is at 1450 nm for fresh sample.

Table 1 shows repeatability and reproducibility of fresh soil and soil powder obtained by FT-NIR spectrometer and Micro-NIR spectrometer. The repeatability of FT-NIR spectrometer and Micro-NIR spectrometer for fresh soil was 0.064 and 0.075, respectively and for soil powder was 0.039 and 0.048,
respectively. The SD value that obtained from FT-NIR spectrometer was lower than that of the Micro-NIR spectrometer. This indicated that the FT-NIR spectrometer was more precise than the Micro-NIR spectrometer. The reproducibility of FT-NIR spectrometer and Micro-NIR spectrometer for fresh sample was 0.048 and 0.051, respectively and for soil powder was 0.045 and 0.046, respectively. As expected, the soil powder was more homogeneous than fresh soil. However, the value from FT-NIR spectrometer was slightly smaller than that of Micro-NIR spectrometer which indicated both instruments were comparable.

| Sample | NIR      | Repeatability | Reproducibility |
|--------|----------|---------------|-----------------|
| Fresh soil | FT-NIR | 0.064         | 0.048           |
|         | Micro-NIR | 0.075         | 0.051           |
| Soil powder | FT-NIR | 0.039         | 0.045           |
|         | Micro-NIR | 0.048         | 0.046           |

4. Conclusions
From the results it can be concluded that the FT-NIR spectrometer and the Micro-NIR spectrometer were comparable in the scanning precision point of view. Both instruments could be used for conducting the feasibility test of creating the equation to predict the N P K value in the soil for the durian trees. However the fresh soil scanning was not precise as the soil powder. As such, it is possible that the soil powder scanning will accurately predict more than fresh soil, but need to find additional preparation fees. For the fresh soil scanning, the spectra is effected by moisture content, therefore, the mathematic pre-treatment of spectra before the model development is needed for eliminate the effect.

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