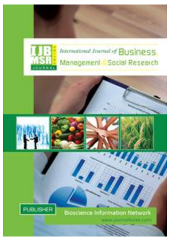
Journal BiNET
Scientific Publication

Published with Open Access at Journal BiNET
Vol. 01, Issue 01: 47-50
International
Journal of Business, Management and Social Research
Home page: www.journalbinet.com/ijbmsr-journal.html



Determination of N mineralization, total N and cation exchange capacity of soil through NIR spectroscopy for decision support in rice farming

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ABSTRACT

Inefficient use of inputs and conventional management practices that are applied during crop production is leading the depletion of soil quality. The inability of conventional farming to address soil variation not only has a detrimental economic impact due to reduced yield but also adversely affects the environment. The need of sustainable management appeals for alternative approaches which will increase the productivity and resources efficiency; and will be desirable in the ecological context as well. Thus, sustainable development has reinforced the process to evolve as a more quantitative manner to optimize soil management and impart spatially differentiated treatments. There is a global need to develop tools that will evaluate soil quality and contribute in the effectiveness and sustainability of farm management. Soil properties delineation at field and landscape scale is extremely important for a variety of agronomic and environmental concerns. The existing knowledge and recent researches (Stenberg et al., 2010) on soil-NIR measurements for soil analysis by the NIR spectroscopic technique could be used potentially for estimation of available nitrogen (N) and cation exchange capacity (CEC) of soils which will optimize fertilization strategy and farmer decision supports. However, this is worth mentioning that NIR measurements are not new in this scientific arena but it has not been practiced so far for estimation of soil properties in Bangladesh. Exploration of its potential would be beneficial for soil property analysis (and or estimation).

Key words: NIR spectroscopy, soil analysis, mineralization, CEC and decision support

Please cite this article as: Siddique M. N. A. (2015). Determination of N mineralization, total N and cation exchange capacity of soil through NIR spectroscopy for decision support in rice farming. *International Journal of Business, Management and Social Research* 01(01): 47-50.

I. Introduction

Nitrogen (N) is one of the important plant nutrients which affect crop production and the ecosystem, and CEC demonstrates the fertility of soils. The management of N is complex but much required due to environmental concern and fertilizer recommendation, while information about CEC is necessary for soil management. Scientists have tried to improve the reliability of determining N fertilizer requirements before sowing and during growing periods. Because, soil N has the potential to be mineralized during the growing season (Lindén, et al., 1992), and large variation between and within fields have been also observed (Börjesson, et al., 1999). This variation needs to be quantified for inputs

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efficiency and to optimize fertilization. The N fertilizer that is applied in soil before sowing is used efficiently by rice crop than top dressing when the application rate is not excessive (Angus, et al., 1990). Thus, it is preferable to apply as much as possible of the optimum amount of N fertilizer at that time. Moreover, excessive N application leads to high risk of yield loss due to cold damage and lodging. While the N uptake by rice crop during the growing periods is another crucial phenomenon and N fertilizer is top dressed during panicle initiation stage; thus the prediction of N uptake in rice crop is important as well. However, failure in justified application of N enhances the risk of decreased or compromised yield and quality. N fertilization strategy should depend on potential yield, crop demand and N supplied by the soils (Delin, et al., 2005). The economically feasible and environmentally suitable strategy for N application requires accurate information on N mineralization so the determination of total available N in soil is crucial. While information on CEC is equally important as it is a key indicator of soil fertility. But the conventional exhaustive technique for N and CEC determination involves tedious sample preparation and laboratory analysis by chemicals. The conventional soil analysis is expensive and time consuming. Hence, there require alternative method as such NIR spectroscopy for soil analysis.

II. Materials and Methods

Methodology that is involved with NIR spectroscopy includes desired soil sampling, sample preparation, data pretreatment and spectroscopic multivariate calibration for prediction equation development and calibration.

Soil sampling: Soil samples could be collected after a growing season from targeted rice fields. Among the existing sampling methods, such as grid, random (simple and stratified), continuous, adaptive; the adaptive sampling (sampling on previous information) and stratified sampling (heterogeneous soils; homogeneous sub-population isolated as strata), could be used for soil sample collection. For the estimation of N and CEC on field scale, and or preferably at regional scale eventually it could increase the number of samples.

Sample preparation and data pretreatment: The soil samples require being freeze dried, grinded and sieved (2 mm) before sample setting for the spectral measurements. Soil spectra (1300-2500 nm) data collection will be done with a Spectrophotometer. All spectra recorded will be checked visually, necessary preprocessing will be done to correct for non-linearities, sample variations and noisy spectra. Most spectroscopy-dedicated software contains a collection to choose (Viscarra Rossel, 2008) from the preprocessing transformations techniques, such as Multiplicative Scatter Correction; first and second derivatives; smoothing methods (averaging spectra) etc. could be used depending on data sets to identify the more chemically relevant peaks in the spectra.

Spectroscopic multivariate calibrations: It consisted of a crucial task associated with the calibration phase for prediction equation development and a validation phase. During calibrations, careful selection of the calibration and validation samples will be done. The size and distribution of the calibration data set will be representative not only of the variation in the soil property being considered, but also of the variation in the spectra. The validation samples will be independent of the calibration samples. However, Principal Component Regression (PCR) and or Partial Least-Squares Regression (PLSR) will be used to calibrate the spectral data with reference soil data which will enable relating the NIR spectra to estimate soil properties (Stenberg et al., 2010) such as values of N and CEC in the soils.

III. Discussion

Near Infrared Reflection (NIR) spectroscopy has attracted interest among soil scientists as a possible technique for improved soil analysis for its rapid, non-destructive, cheap measurements as well as possibilities to determine several soil properties simultaneously. During the last two decades, the visible and near-infrared spectroscopy has proved to be a convenient analytical technique that correlates diffusely reflected near-infrared radiation with the physico-chemical properties of materials. A single spectrum allows for simultaneous characterization of various soil and grain constituents. Additionally, NIR spectroscopy has advantages over some of the conventional techniques,

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such as rapid, timely and less expensive, thus are more efficient when a large number of analysis and samples are required. Moreover, spectroscopic techniques require minimal sample processing and no use of harmful chemicals. This technique is sometime more straightforward than conventional soil analysis and occasionally also more accurate (Shepherd & Walsh, 2002; Chang and Laird, 2002; Brown, et al., 2006; Viscarra Rossel, et al., 2006). Fuentes et al. (2012) stated that ‘‘advances in laboratory instrumentation and chemometrics provide alternatives to traditional methods of conducting soil chemical analysis. One of these is infrared diffuse reflectance spectroscopy in the near-infrared spectral range (NIRS)’’. While Norris et al. (1976) stated that ‘‘conventional analytical methods exchangeable individually for most of the soil properties which are time consuming, destructive of samples and often use many chemical reagents. The advantages of using NIR reflectance spectroscopy include the simplicity of sample pre-treatment (sieving of soils), its lack of chemical reagents, its non-destructive nature, and the fact that it is rapid, inexpensive and accurate for analysis’’. However, NIR spectroscopy shows considerable potential to predict soil available N, CEC and the associated calibration models (He, et al., 2005; Stenberg, et al., 2005; Wetterlind, et al., 2008; Nduwamungu, et al., 2009; Kuang and Muazen, 2011), to assess the fate and transport of N in soils and crop, and may assist fertilizer decision support (Russel, et al., 2002).

Thus, development of NIR measurements for available N and CEC, formulation of calibration models and spectral relationships to N-mineralization could be potential finding for optimizing fertilizer management during rice growing seasons in Bangladesh. Consequently the estimation of N and CEC will be possible and it will help the development soil information database for farmer decision supports and resource use efficiency. The planning for fertilizer application strategy could become possible depending on the available N and CEC status of soil. Furthermore, potential soil analysis results derived from NIR spectroscopy could increase the efficiency of inputs and farm management options by allowing the farmer and producer to manage crops on both spatial and temporal basis with a prescriptive manner rather than conventional farming.

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