

# Quick and Simplified on-farm Tests to Determine Nitrate Levels in Soil

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**Abstract:** Crop management can be optimized and nitrogen losses can be reduced with a better knowledge of soil nitrogen availability especially if this information becomes directly available on-site in a fast and cost-effective way. In this paper simple on-farm methods to determine nitrate-nitrogen in field-moist soil samples immediately after sampling are described. The developed procedures include volumetric soil sampling, extraction based on manual shaking with tap water as universally available extractant, filtering soil/extractant mixtures on-site, on-site determination of the soil water content and reflect metric nitrate measurements based on test strips. Using correction factors can compensate the impact of the temperature during the final nitrate measurement. An excellent agreement was found between the developed quick-test procedures and the standard laboratory procedure. The proposed quick-test has great potential to enable economical savings for farmers as well as benefiting the environment.

**Key words:** extractant, field test, reflectometer, residual nitrate, soil water content

## Introduction

A better knowledge of soil nitrogen availability is crucial for optimizing crop management and for reducing the nitrogen contamination of groundwater and other nitrogen losses. Residual nitrogen should be taken into account in fertilization decisions and regular soil nitrate analyses are needed. However, the often-times inadequate handling of soil samples leading to unwanted mineralisation and nitrification, time delays until the farmer gets the result, and the high costs reduce the acceptance of more frequent soil residual nitrogen analyses.

In recent years, substantial effort has been directed towards improving the situa-

tion, with major efforts being targeted at simplifying the analytical part of the soil mineral nitrogen investigations. Simplified quick-test methods such as nitrate-sensitive colorimetric test strips (Schaefer, 1986; Jemison and Fox, 1998; Roth *et al.*, 1991; Schmidhalter, 1994) for immediate nitrate analysis have been suggested. By contrast, comparatively little effort has been directed towards simplifying the steps preceding the nitrate analysis. This includes simplified procedures for extracting, shaking and filtering soil/extractant mixtures on-site; on-site determination of the soil water content; extractants that require no pre-processing. This paper describes a simplified on-field/on-farm soil nitrate analysis of residual nitrate nitrogen. Further details including a procedure to obtain instantaneously volumetric soil samples are presented in a companion paper (Schmidhalter, 2005).

## Materials and methods

The investigated soils encompass a wide range of soil textures, ranging from sandy to loamy and clayey soils with variable nitrate contents. Distilled water, tap water, and bottled mineral water with known mineral composition were tested as extractants together with 0.01M $\text{CaCl}_2$ . Soil/extractant mixtures are either hand-shaken for 1, 3, 5 minutes, or for one hour using a laboratory shaker. A sub-sample of about 100g moist sieved soil, weighed with an inexpensive solar-driven kitchen balance, is filled into a 325 ml flask, to which 150 ml extractant is added (on-farm method [A]). The flask is then capped and manually or mechanically shaken for an appropriate time interval. With the on-farm method [A], the soil water content of a separate subsample is gravimetrically determined after air/oven-drying. An alternative method is used to determine soil water content that does not require any drying of separate moist soil samples. A 500 ml plastic cylinder is filled with 250 ml extractant and about 100 ml sieved moist soil added (on-farm method [B]). The weight of the added moist soil is determined with an inexpensive solar-driven kitchen balance. The cylinder is capped and shaken for a recommended time. Using appropriate values for the particle density, gravimetric soil water contents can be determined instantaneously with a gravimetric-volumetric technique as described in the companion paper (Schmidhalter, 2005). Nitrate is measured in the clear solution collected in a filter paper, which is placed in a funnel-like fashion in the muddy solution, or without any filtering after 10~20 minutes settling time. Nitrate concentrations are determined reflectometrically using nitrate test strips and a reflectometer (Reflectoquant® Nitrate Test and Reflectometer RQflex, E. Merck, Darmstadt, Germany). The temperature dependence of the nitrate test strips was investigated in the range from 6~30°C.

## Results

As compared to distilled water 0.01 M  $\text{CaCl}_2$  is preferred as extractant because it flocculates suspended particles and obtains a clear supernatant after only a short settling time. Nitrate-free or nitrate containing Ca-containing bottled mineral waters represent very simple extractants and can also be used successfully for soil nitrate analysis. Similarly, tap water with previously determined nitrate contents can also be used. Intensive hand shaking in extraction flasks obtained adequate recovery of nitrate within a few minutes; for most soils, only 3~6 minutes of hand-shaking are adequate. Slightly reduced recoveries for heavier soils can be improved by longer shaking times or by using correction factors. Gravimetric soil water contents can be determined with the gravimetric-volumetric technique to a precision of  $\pm 2\% \sim 3\%$  of the actual gravimetric soil water content.

Both simple on-farm soil tests to determine nitrate-nitrogen in field-moist soils immediately after sampling show good performance. The agreement between the on-farm method [A] and a standard laboratory method was very good (Fig. 1). An excellent agreement was also obtained with the on-farm method [B] and a standard laboratory method (Fig. 2).

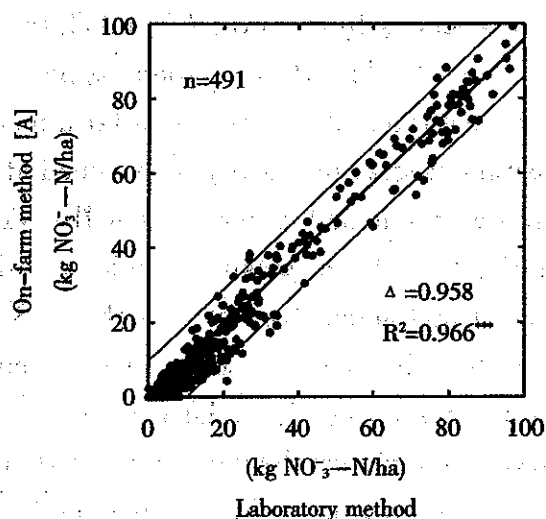


Fig. 1 Comparison of soil nitrate-nitrogen contents measured by a standard laboratory procedure and the on-farm-method [A]

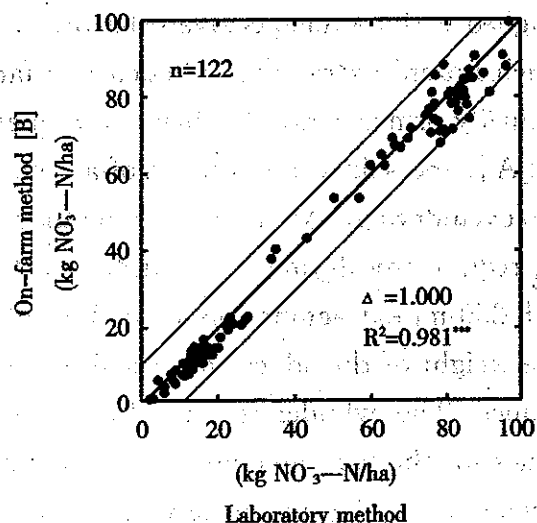


Fig. 2 Comparison of soil nitrate-nitrogen contents measured by a standard laboratory procedure and the on-farm method [B]

The temperature dependency of nitrate test strip measurements is shown in Fig. 3. Nitrate values obtained at non-optimal temperatures have to be corrected through appropriate factors. No temperature correction is required at a temperature slightly below  $20^{\circ}\text{C}$ . Temperature readings can be obtained with inexpensive thermometers.

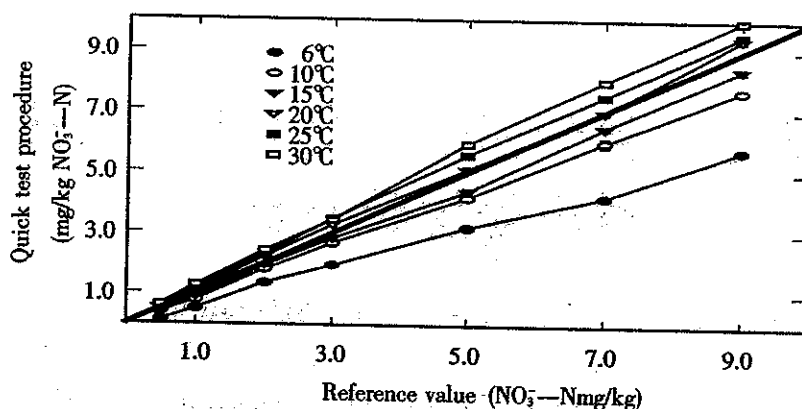


Fig. 3 Temperature dependency of colorimetric nitrate test strip measurements.

## Conclusions

The excellent agreement between our suggested quick-test procedures and a standard laboratory test procedure points to a significant improvement in the determination of residual soil nitrate contents in a simplified, fast and cost-effective way. These methods not only allow more frequent determinations, but they are also cheaper and deliver the result in a much shorter time because of their reliance on universally available extractants and simplified extraction/filtering procedures. As such, further transportation, critical handling for preventing unwanted mineralisation and storage are no longer required. The possibility to immediately determine on-site gravimetric soil water contents represents a significant improvement. Highly reliable test results can be obtained in a very short time. In conclusion, the quick test procedures we propose herein demonstrate great potential and should contribute to economical savings as well as benefit the environment.

## Reference

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