

On-farm soil nitrate-nitrogen test

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Abstract

Simple on-farm/on-field soil methods to determine nitrate-nitrogen in field-moist soil immediately after sampling are described. These novel methods are rapid, reliable and inexpensive. The measurement of soil nitrate and water content can be performed on-site and instantaneously with field moist soil samples and without unwanted mineralisation. Inexpensive and universally available extractants can be used. No filtering is required. Nitrate measurements are conducted reflectometrically with colorimetric test strips. The agreement of the new-quick test procedures with a standard laboratory method was excellent. The quick-test procedures demonstrate great potential and should contribute to economical savings as well as benefiting the environment.

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 situation, 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 simplified procedure to obtain volumetric soil samples are presented in a companion paper (Schmidhalter, 2005).

Materials and methods

The investigated soils encompassed 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 0.005 and 0.01 M CaCl₂. Soil/extractant mixtures were either hand-shaken for 1, 3, 5 minutes, or for one hour using a laboratory shaker. A subsample of about 100 g moist sieved soil, weighed with an inexpensive solar-driven

kitchen balance, was filled into a 250-mL flask, to which 150 mL extractant was added (*beaker method*). The flask was then capped and manually or mechanically shaken for an appropriate time interval. With the beaker method, the soil water content of a separate subsample was gravimetrically determined after air-/oven-drying. An alternative method was used to determine soil water content that does not require any drying of separate moist soil samples. A 500-mL plastic cylinder was filled with 250 mL extractant and about 100 mL sieved moist soil added (*measuring cylinder method*). The weight of the added moist soil was determined with an inexpensive solar-driven kitchen balance. The cylinder was capped and shaken for a recommended time. Using appropriate values for the particle density, gravimetric soil water contents could be determined instantaneously with a gravimetric-volumetric technique as described in a companion paper (Schmidhalter, 2005). Nitrate was measured in the clear solution collected in a filter paper, which was placed in a funnel-like fashion in the muddy solution, or without any filtering after 10-20 minutes settling time. Nitrate concentrations were 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 6-32°C.

Results

As compared to distilled water, 0.005 and 0.01 M CaCl₂ 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 $\pm 2\%$ - 3% of the actual gravimetric soil water content.

Both simple on-field/on-farm soil tests to determine nitrate-nitrogen in field-moist soils immediately after sampling show good performance. The agreement between the beaker quick test method and a standard laboratory method was very good (Fig. 1). An excellent agreement was also obtained with the measuring cylinder method, which does not require a separate determination of the soil water content, and a standard laboratory method, which requires the drying and weighing of soil samples (Fig. 2).

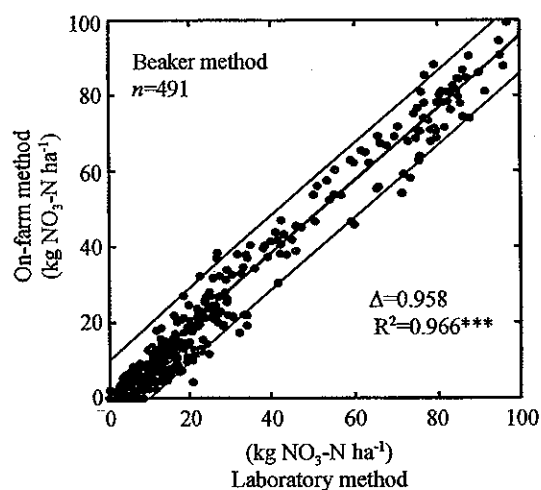


Figure 1. Comparison of soil nitrate-nitrogen contents measured by a standard laboratory procedure and the on-field beaker method.

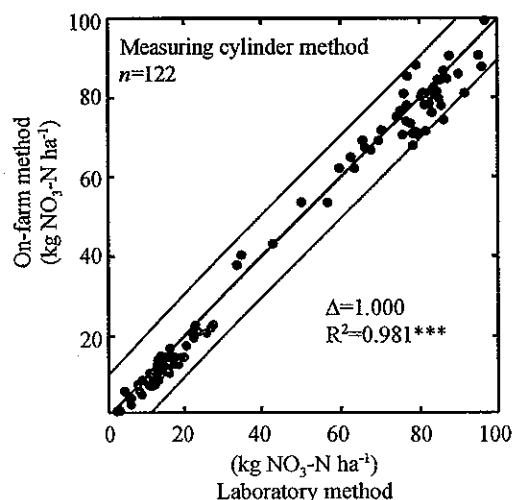


Figure 2. Comparison of soil nitrate-nitrogen contents measured by a standard laboratory procedure and the on-field measuring cylinder method.

The temperature dependency of nitrate test strip measurements is indirectly shown in Fig. 3. Nitrate values obtained at non-optimal temperatures have to be divided

through appropriate correction factors and are indicated in Fig. 3. No temperature correction is required at a temperature slightly below 20°C . Temperature readings can be obtained with inexpensive thermometers.

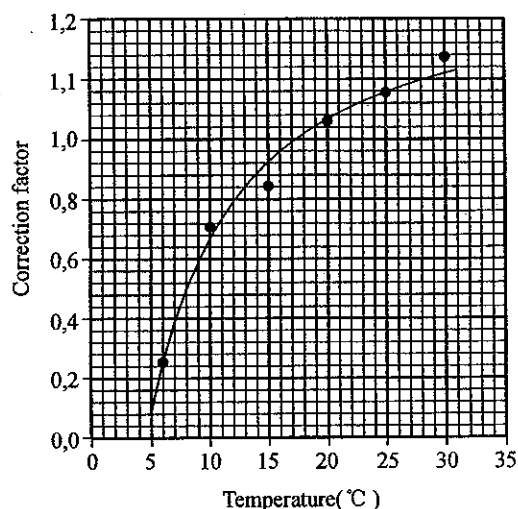


Figure 3. Temperature dependency of colorimetric nitrate test strip measurements. Correction factors for the respective temperatures are indicated.

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.

References

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