ACCURACY OF QUICK SOIL NITRATE TESTS IN MONTANA

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ABSTRACT

Accurate, rapid testing of soil nitrate-N would allow producers to adjust their fertilizer rates when needed and augment their annual soil testing. This study tested the accuracy of three quick test kits on approximately 90 soils. Quick nitrate-N readings were well correlated ($P<0.001$) with laboratory readings. However there was a fairly high probability (~40%) of over or under estimating total soil N by at least 15 lb N/ac. In addition, regression coefficients between quick test and laboratory test data varied by up to a factor of 2.2 among 5 individuals who verified these methods; therefore, individual calibration of the methods will be necessary to obtain the most accurate results.

INTRODUCTION

Optimizing N fertilizer rates based on soil nitrate results is critical for maximizing yields, increasing fertilizer use efficiency, and decreasing N leaching. Fertilizer N rates in Montana are generally calculated based on fall sampling due to the short time periods between when a soil can be sampled in spring and seeding. However, N mineralization rates from fall to spring can vary greatly between soils (Malhi et al., 1985) and depend on what month 'fall' sampling was completed. In addition, decisions on whether or not to topdress need to be made in a timely manner. Finally, costs of lab analyses may discourage some producers from analyzing nitrate levels from many fields. Accurate instantaneous measurement of soil nitrate-N would allow producers to optimize N fertilizer rates at both seeding and topdressing times. Several relatively inexpensive home test kits are available, although very little published work is available on the accuracy of these methods. Hartz (1994) and Hartz et al. (2000) showed good correlation of nitrate-N levels in irrigated soils for vegetable production between two types of quick test kits and lab analyses. This study correlated nitrate levels of three different quick test kits to laboratory analyses to determine their accuracy in a wide range of Montana soils.

MATERIALS AND METHODS

Eighty-nine soil samples were collected from 52 sites in Montana representing nine counties. Both 0-6 in. and 6-24 in. samples were collected from 37 sites, and only the upper 6 in. were collected from the remaining 15 sites. All soils were homogenized, and sub-samples were sent to one university and one independent laboratory. The MSU Soil Testing Lab (Bozeman, Montana) analyzed nitrate-N, pH, soil water content and texture, while MDS Agronomic Services Laboratory (Lincoln, NE) analyzed nitrate-N only. All soils were extracted with a DI H_2O:soil ratio of 3:1 (v/v), shaken for one min. A ¼ teaspoon of Epsom salt ($MgSO_4 \cdot 7H_2O$) was subsequently added as a flocculent and the mixture was shaken for 10 s. Solutions were left undisturbed for 2 h to allow the soil to settle.

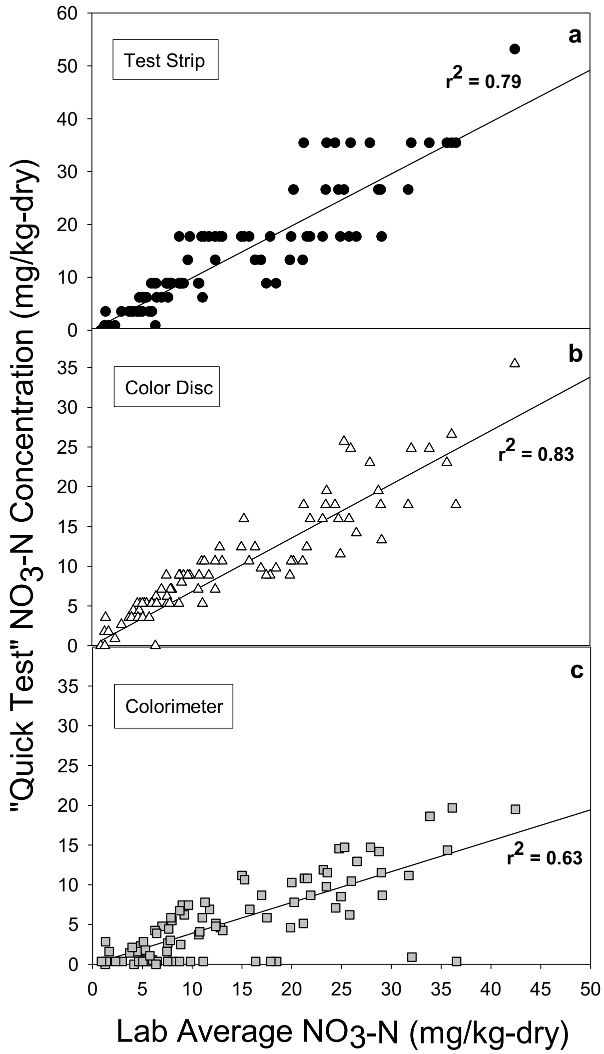

Figure 1. Comparison of nitrate-N concentrations between three quick tests and lab analyses (a two lab average). Measured quick test nitrate-N (mg/L) concentrations were converted to mg/kg-dry soil using average moisture content, soil mass and water volume.

The test strip (WaterWorks™ Sensafe, 480009) required dipping the end of a strip into the solution for 2 s, waiting 60 s for the color to stabilize, and then comparing the strip color to the chart on the bottle. The color disc (Hach™ NI-11) method consisted of withdrawing two 5 mL aliquots of the clarified solution and dispensing them into two vials. A cadmium (Cd) reagent was added to one for colorimetric determination of nitrate-N in solution, while the other was used as an analytical blank. The vial with reagent was shaken for 60 s and then allowed to react for 60 s. The user matched the vial's solution color to the corresponding nitrate-N concentration. The colorimeter method (Hach Pocket Colorimeter™ II) consisted of withdrawing two 10 mL aliquots of solution and dispensing them into 2 vials. This method also required a cadmium (Cd) reagent for colorimetric determination of nitrate-N. The vial with reagent was shaken for 30 s, allowed to react for 5 min., and then placed in the colorimeter to measure the level of nitrate-N compared to the blank. Ten percent of the samples were randomly selected, sub-sampled and analyzed in duplicate to determine analytical precision. Average relative standard deviation for nitrate-N using test strip, color disc and colorimeter methods were 3.8, 12, and 49%, respectively.

All data analyses used average soil mass and moisture content because most end users of these methods would not have access to a scale. Regression analyses between quick method nitrate-N readings and lab average nitrate-N were conducted to determine regression coefficients (m) for the equation y = mx. These coefficients were multiplied by nitrate-N readings to obtain calculated nitrate-N values which were compared to lab average nitrate-N to estimate error. Total nitrate-N (lb/ac) was computed by multiplying the 0-6 in. nitrate-N readings (mg/kg) by 2, the 6-24 in. readings by 6 and summing the nitrate-N (lb/ac) of the two depths.

RESULTS AND DISCUSSION

Out of 89 soil samples with a range of 0-45 mg/kg nitrate-N, the color disc nitrate-N results had the highest correlation to the lab average nitrate-N (r^2=0.83) while the test strip and colorimeter methods had r^2 values of 0.79 and 0.63, respectively (Figure 1). Correlations improved to 0.89, 0.85, and 0.66 for the color disc, test strip, and colorimeter, respectively, when actual soil moisture content and soil mass were used in the analyses.

The correlations of test strip and color disc nitrogen data with lab data were similar to the correlations between nitrate-N data for the two labs (r^2=0.89) (data not shown). The higher correlation for the color disc may be a result of the continuous range of color gradations on the color disc than the test strip. This reduced the need for interpolation and increased accuracy. The test strips had coarse gradations on the provided chart, which increased the need for interpolation. The poor correlation of the colorimeter results may be attributed to instrument malfunction or interference. Based on the high number of samples that read below the detection limit, the colorimeter method was excluded from the remainder of the analyses.

Table 1. Correlation coefficients (r) between error in nitrate-N concentrations (mg/kg) and soil water content, clay content and soil pH. Error was calculated by subtracting lab average nitrate-N from calculated quick test nitrate-N.

	Water Content	**Clay Content**	**pH**
	---------------- **r**	--------------	
Test Strip N error	- 0.52***	- 0.06	0.1
Color Disc N error	- 0.55***	- 0.02	0.09
Colorimeter N error	- 0.20*	- 0.04	- 0.09

*, *** - significant at P<0.05, 0.001, respectively

Error in nitrate-N concentrations was compared to soil water content, clay content and pH to determine if these variables were affecting quick test nitrate-N readings (Table 1). Data from the 89 soils showed that clay content and pH did not significantly affect nitrate-N error for the three methods. Water content did significantly affect nitrate-N error for the test strips and color disc ($P<0.001$) and less significantly for the colorimeter ($P<0.05$). This analysis indicated that with increased soil water content, nitrate-N concentrations became diluted resulting in lower readings than lab nitrate-N results. However, when a subset of 15 soils was dried and tested with all three methods, the correlations were inconsistent suggesting that drying did not improve accuracy.

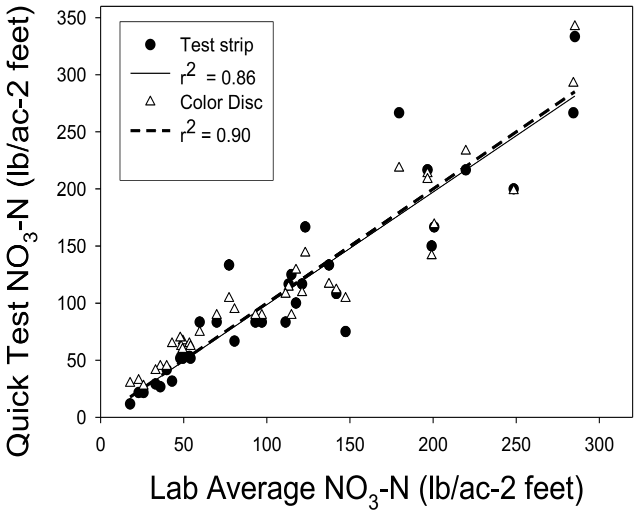

Figure 2. Comparison of laboratory nitrate-N and calculated nitrate-N in lb/ac for the test strip and color disc methods for 37 sites, that had both sample depths (0-6 in. and 6-24 in.).

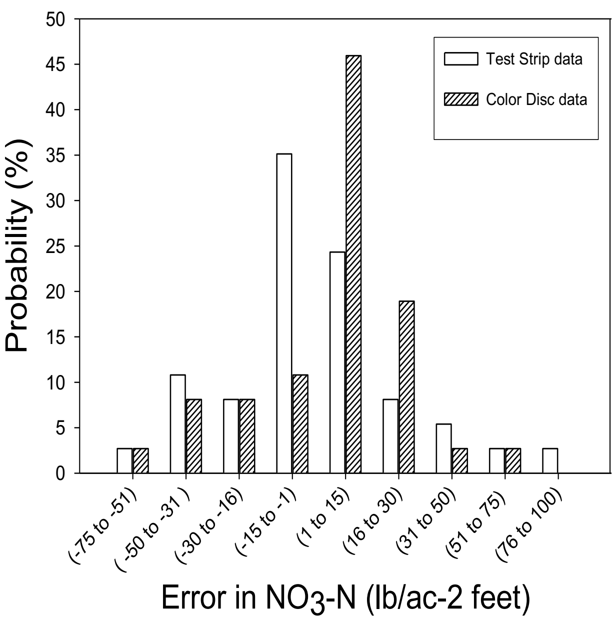

Figure 3. The probability of under or over-estimating soil nitrate-N (lb/ac) using the test strip and color disc methods.

Correlations between quick test total nitrate-N (lb/ac) in the upper 2 feet and lab nitrate-N (lb/ac) were better than between nitrate-N concentrations (Figure 2). Summing nitrate-N (lb/ac) over two depths smoothed the data and more heavily weighted the lower depths where lower NO_3-N concentrations resulted in less error (data not shown).

There was a 35 to 45% probability of under or over-estimating laboratory nitrate-N by at least 15 lb/ac (Figure 3). If relied on as accurate, producers may under-fertilize and experience reductions in yield or grain quality, or over fertilize, resulting in higher input and operation costs.

When the test strip and color disc methods were verified by five individuals, there was a moderate degree of variability between users (Figure 4). The correlation of individual results to lab analyses for the test strips was better than the original data set (r^2 values of 0.78 to 0.87, with an average r^2 of 0.83). The correlation of individual results for the color disc method resulted in a wider range of r^2 values (0.70 to 0.94) with a slightly lower average r^2 (0.80) compared to the original data set. More importantly, the regression coefficients (slopes) between quick test and lab data for the five individuals ranged by factors of up to 2.2 and 1.8 for the test strip and color disc methods, respectively. Therefore, if one correction factor was used to calculate nitrate-N from a quick test as previously recommended (Hartz et al., 2000), an error of approximately 100% could be introduced depending on individual interpretation of color.

CONCLUSION

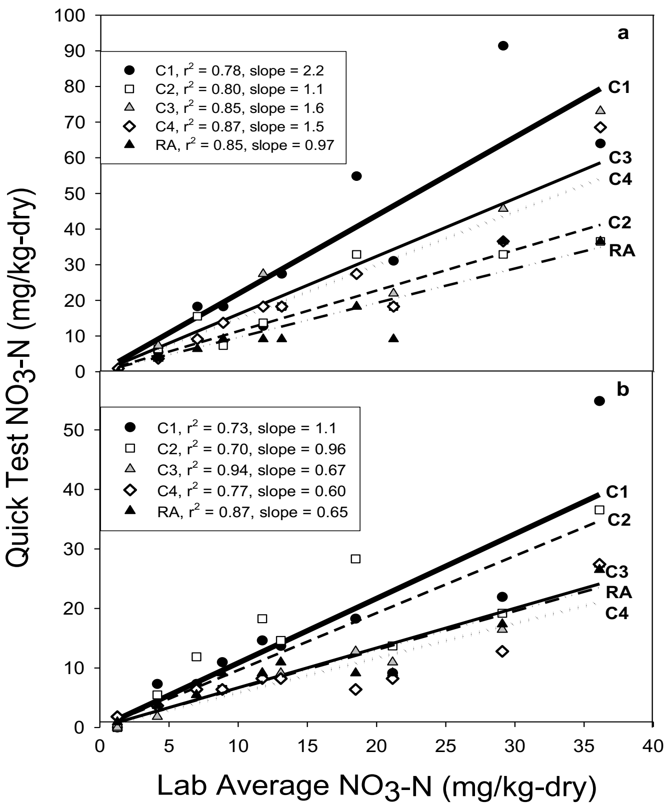

Figure 4. Variability of results in using either test strip (a), or color disc (b) methods. Ten soils, selected by double blind, random sampling were tested by 4 individuals (C1- C4) and the project research associate (RA). Results compare lab average (a 2 lab average) nitrate-N to quick test nitrate-N.

In summary, out of the three quick tests evaluated, two (the test strip and color disc methods) had consistently better correlations with lab analyses. Correlations across all tests were likely too low to have confidence in these methods due to the possibility of introducing a relatively large error in nitrate-N (lb/ac). Soil moisture content was found to significantly affect nitrate-N readings and could be corrected for if the user had a gravimetric scale. Individual users can increase the accuracy of the quick tests by following a consistent methodology and calibrating their readings. These quick tests need to be used in conjunction with laboratory nitrate-N analysis until the user is satisfied with the calibration.

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