SHORT NON-REFEREED PAPER

TOWARDS A MORE ACCURATE PREDICTION OF NITROGEN RESERVES IN THE SOIL FOR CROP GROWTH

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Abstract

The accurate quantification of potentially mineralisable N reserves in soils is of great importance in terms of the estimation of crop N requirements. For the past 20 or so years, the Fertiliser Advisory Service (FAS) at the South African Sugarcane Research Institute has made use of the 'N category' approach in predicting N release in soils. Nitrogen categories, as used by the FAS, are based on soil total organic matter and clay contents. To further improve the accuracy of FAS N recommendations, the effects of variations in the composition and stability of soil organic matter on N availability are under investigation. In this study, N release from 114 topsoil samples largely representative of soils of the South African sugar industry was investigated using laboratory incubations and chemical tests, with a view to effecting an improvement on the N category approach currently in use. Nitrogen release following 28 and 112 day aerobic incubations did not closely concur with predicted N release using FAS soil N categories. The correlations for N release of various chemical tests (7-day anaerobically mineralisable N, hot water extraction and hot 2 *M* KCl extraction, 3-day CO_2 flush) with the 28 and 112 day aerobic incubation data were stronger (r values ranged from 0.57 to 0.84) than the correlations with N category (r range = 0.18 to 0.24). This paper discusses the potential value of these tests for routine soil testing in a high throughput laboratory.

Keywords: N management, potential N mineralisation, N tests, N category, soil organic matter, incubation studies

Introduction

An improvement of nitrogen (N) use efficiency is an economic and ecological imperative. However, a better adjustment of N application to crop demand requires that the N released by the soil is accurately predicted. In the SA sugar industry, prediction of N mineralisation is currently based on categorising soils into four N categories based primarily on their total soil organic matter (SOM) levels, and to a lesser extent on clay content; variations in the composition and stability of the SOM are not taken into account in this approach.

The most accurate measurements of potential N mineralisation are long term incubations under controlled temperature and moisture regimes; these are, however, very time consuming and not suitable for use in routine soil testing. Research undertaken in overseas countries (Schomberg *et al*., 2009; Franzluebbers *et al*., 2000) has shown that there are several rapid soil N tests which may provide reasonably accurate estimates of N mineralisation. In this

study, the more promising N tests reported in the literature (7-day anaerobically mineralisable N, hot water and hot 2 *M* KCl extractable N, and 3-day flush respiration) were selected for evaluation in terms of the prediction of N mineralisation determined in long term incubations.

Materials and Methods

Topsoil (0-20 cm) samples (n=114) were collected between September 2008 and May 2011 from fields in the South African sugar industry. The sample set is considered to be a fair representation of the industry's most widespread soil forms. Management differences were burnt versus trashed, with the majority of the samples (76%) being from burnt fields. About 10% of the samples came from irrigated areas and another 12% were from virgin, non-cultivated areas adjacent to production fields. The samples were air-dried and gently crushed through a 2 mm sieve, prior to long-term incubation. Samples used in the chemical tests were sieved to <1 mm.

The N category (N cat) index as used by the Fertiliser Advisory Service at the South African Sugarcane Research Institute (SASRI) was developed by Meyer *et al*. (1986), where soils are placed into four N mineralisation categories (1=low to 4=high), based on organic matter and clay contents. Based on the methods of Franzluebbers *et al*. (2000) and Klimanek *et al*. (1995), a long term incubation experiment was initiated where 200 g air-dried soil was adjusted to 50% water holding capacity with distilled water and homogenised. The sample was divided into six sub-samples and incubated at 25°C. The six sub-samples were used for analysing mineral N release at days 7, 14, 28, 56, 84 and 112. For this short paper data from the 28 day incubation was used, with mineral N at commencement of incubation either subtracted (N-28) or included (N-28+). In addition, use was made of the maximum N release value during the 112 day incubation, with mineral N at the start either included (N-max+) or excluded (N-max).

Total C and total N were determined by dry combustion using a Leco C/N analyser. Mineral N was determined following extraction with 2 *M* KCl. The short term anaerobic incubation (Anaer N) was based on the method of Keeney and Bremner (1966), where a 5 g air-dried sample was incubated in 12.5 ml water at 40°C over a period of seven days. Hot KCl extractable N (Hot KCl N) was analysed according to the method of Gianello and Bremner (1986), which involved boiling in 2 *M* KCl for four hours. Nitrogen in all extracts was determined by a segmented-flow auto analyser method. Hot water extractable N (HWEN) was determined by the method described by Schulz *et al.* (2003), where 20 g of air-dried soil was boiled in 100 ml of distilled water under reflux for one hour. The N content of the extracts was analysed in a Shimadzu C/N analyser at 680°C. The three day flush respiration (C-flush) was determined by the method described by Franzluebbers *et al*. (2000), where 40 g air-dried soil was adjusted to 50% water-filled pore space and incubated in a sealed container with 10 ml of 1 *M* NaOH for trapping the CO_2. After three days at 25°C, the quantity of CO_2 released was determined by titration with $BaCl_2$.

Results and Discussion

The Pearson correlation coefficient r for all tested parameters is presented in Table 1. The strongest correlation of 0.97 was found between total organic C and total N content. However, the correlations of total organic C and total N with the N mineralisation indices were generally weak, the best correlations being with the three day CO_2 flush (r=0.68 and 0.74). The N release in 28 days (N-28+) was strongly correlated (r=0.97) with the maximum

N-release within 112 days of incubation (N-112+). Clearly, therefore, a shorter incubation over 28 days describes the N mineralisation of the soils with almost the same accuracy as the long term 112 day incubation.

Table 1. Pearson correlation coefficients for soil total carbon and nitrogen, N mineralisation indices and nitrogen released in long term incubation studies.

	C %	N %	N cat	N-28+	N-28	N-max+	N-max	Anaer N	Hot KCl N	HWEN	C-flush
C %	-										
N %	0.97*	-									
N cat	-	0.56*	-								
N-28+	0.48*	0.53*	0.22	-							
N-28	0.50*	0.57*	0.18	0.81*	-						
N-max+	0.53*	0.58*	0.24	0.97*	0.80*	-					
N-max	0.55*	0.63*	0.22	0.78*	0.94*	0.85*	-				
Anaer N	0.56*	0.66*	0.28	0.78*	0.73*	0.83*	0.80*	-			
Hot KCl N	0.54*	0.56*	0.30	0.84*	0.57*	0.84*	0.61*	0.80*	-		
HWEN	0.51*	0.52*	0.17	0.76*	0.61*	0.79*	0.66*	0.61*	0.59*	-	
C-flush	0.68*	0.74*	0.43*	0.58*	0.67*	0.65*	0.75*	0.73*	0.53*	0.63*	-

*significant correlations at P <0.001.
Increasing strength of correlation is reflected by increasing intensity of shading.

The correlation results of the various N tests and with the incubation data ranged between 0.58 and 0.84. For Anaer N (r=0.83), Hot KCl N (0.84) and HWEN (0.79) the correlations were stronger with the incubation data when the initial inorganic N was not subtracted (N-28+ and N-112+), showing that the initial N content of the samples had a distinct influence on the results. The opposite was true for the C-flush which better related to N-28 and N-max (r=0.67 and 0.75). The N category (N cat) index was not significantly related to either the amounts of N released in incubations nor to the N released in N tests. Weak to medium correlations were found for N cat with total N% (r=0.56). It is noteworthy that the correlations between N released by incubation and the various N-tests, in particular Anaer N and Hot KCl-N, although highly significant, did not approach the levels of significance noted in similar studies reported in the literature. Schomberg *et al.* (2009) reported a correlation coefficient of above 0.9 for both methods, while C-flush resulted in a strong coefficient of 0.86. However, soils included in this study are far more heterogeneous than those used by Schomberg *et al*. (2009) and Franzluebbers *et al*. (2000), where samples were drawn from long-term experiments with treatments differing largely in organic matter content, and apparently not much in texture and mineralogy. Factors which are suggested to contribute to a higher variability of our data set are: the inclusion of various soil forms, samples were taken from a wide range of climatic conditions and management regimes (high environment x management interaction), the inclusion of a relatively high percentage of light sandy soils and soils low in organic matter (21% soils <15% clay and <1% carbon), the samples were taken all year round (no specific sampling season) and the storage time varied from 0 to 31 months. It is likely that the variability could be reduced by specifying the sampling conditions, sampling times and storage times. Nevertheless, with the current objective being the development of a practical approach for routine use, methods must be robust enough to give N predictions with a fair degree of accuracy, irrespective of sampling and soil conditions.

Conclusions

Total C, total N and N category were all relatively poorly related to the N mineralisation measured in long-term incubation trials. This finding is in agreement with numerous literature reports of indices based on total organic matter and total N being unreliable indicators of soil N supplying capacity. In the case of the N category parameter, this implies the need for a more reliable index of N mineralisation. The correlations for N release of various chemical tests (Hot KCl N, Anaer N, HWEN and C-flush) with the 28 and 112 day aerobic incubation data were highly significant (r values ranged from 0.57 to 0.84) and represent an improvement on the N category approach. Further investigations are under way, with a view to identifying the most reliable index for use in a high throughput routine laboratory. Investigations include the use of mid-infrared spectroscopy for predicting available N reserves in soils.

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