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ASSESSING THE RELATIONSHIP BETWEEN COMMON MEASURES OF SOIL CU AND ZN STATUS AND SOIL UREASE ACTIVITY OF DAIRY-GRAZED PASTURE SOILS

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Abstract

Intensification of dairy farming in New Zealand (NZ) over the last three decades has resulted in a substantial increase in the use of urea nitrogen (N) fertiliser and, as a consequence, higher ammonia (NH_3) emissions. The annual loss of NH_3 from urea fertiliser is estimated to be worth about $30 million. The urease inhibitor, N-(n-butyl) thiophosphoric triamide (nBTPT) sold under the trade name Agrotain® is one of the most promising approaches for reducing NH_3 emissions by inhibiting soil urease enzyme activity (UEA) when applied with urea fertiliser or cattle urine. However, nBTPT inhibition of soil UEA and NH_3 emissions is short-lived (7-14 days) requiring repeated applications immediately after each grazing for effective reduction in NH_3 loss from urine spots. Micronutrients such as Cu and Zn also have potential to inhibit soil UEA and reduce NH_3 emissions over a longer duration than nBTPT.

Here, we present the relationship between common measures of soil Cu and Zn status i) total acid recoverable and ii) ethylene-diamine-tetra-acetic acid (EDTA) extractable vs. soil UEA of 24 dairy farm soils from the Waikato region contrasting in soil carbon (C) and, Cu and Zn status. No significant negative correlations between Cu and Zn levels measured using either of two tests and soil UEA were observed. The lack of such a relationship could possibly be attributed to the inability of these tests to adequately represent their bioavailability for microorganisms and plants. However, soil total C levels showed a significant positive correlation with soil UEA. We propose the measurement of bioavailable Cu and Zn levels in future work to better understand the relationship between soil UEA and soil Cu and Zn status.

Introduction

Intensification of dairy farming in NZ over the last three decades has resulted in a substantial increase in use of urea N fertiliser and, as a consequence, higher NH_3 emissions. Ammonia emissions represent economic losses of N fertiliser and have negative impacts on the environment. Annual losses of NH_3 from urea fertiliser used on NZ farms are estimated to have a value of about $30 million (Ballance Agri-Nutrients, Press Release 31 March 2015). Mitigations that reduce these losses would provide an approach to improve N use efficiency on farms and reduce the environmental impacts and economic losses. Various urease inhibitors (hydroxyurea, phenyl phosphorodiamidate (PPDA), nBTPT, alk(en)yl thiosulfinate, hydroquinone, p-Benzoquinone, caprylohydroxamic acid, acetohydroxamic acid) have been used to inhibit soil UEA and reduce NH_3 losses, though most have shown restricted potential as fertiliser amendment because of lack of stability in fertiliser, low effectiveness, or lack of sustained action (Singh, 2007). Among urease inhibitors, nBTPT, sold under the trade name Agrotain® has recently been identified as one of the most promising and efficient approaches for reducing NH_3 emissions by inhibiting soil UEA when applied with urea fertiliser or cattle urine (Saggar et al., 2013). Subsequently, Zaman et al. (2013) found that 5 to 10 mm of irrigation/rainfall is needed very soon (<8 hr) after urea application to supress NH_3 emissions depending on initial soil moisture contents. Delaying irrigation for 48 hr post urea application resulted in high average NH_3 losses of 23% and 28.3% for urea applied at 30 and 60 kg N ha^{-1}, respectively. Even when 5 or 10 mm of irrigation was applied 8 hr after urea application, average NH_3 losses were still 11.3% and 14.4% of the N applied at 30 and 60 kg N ha^{-1}, respectively. If this irrigation/rainfall is not guaranteed, then NH_3 losses associated with standard urea application can effectively be reduced by 47% using urea treated with nBTPT. However, inhibitory effect of nBTPT on soil UEA and NH_3 emissions is effective for a relatively short period of time, 7-14 days (Saggar et al., 2009), during which NH_3 emissions from urea are inhibited. But, in the context of grazed pasture, to reduce the NH_3 emitted from the deposition of urine following each grazing event, regular applications of nBTPT are required.

Micronutrients such as Cu and Zn also have potential to inhibit soil UEA and reduce NH_3 emissions over a longer duration compared to nBTPT (Hemida et al., 1997; Junejo et al., 2013). The efficiency of Cu and Zn to inhibit soil UEA and reducing NH_3 emissions depends on soil properties (e.g., pH, moisture content, temperature, organic matter content, trace elements status) and concentration applied. Cu and Zn status of soils could be the one of soil factors which could have influence on soil UEA and NH_3 emissions. There is variation in inherent soil Cu and Zn levels in NZ pastoral soils. However, there is minimal NZ and international information on the influence of inherent soil Cu and Zn levels on soil UEA and on NH_3 emissions. Common measures of soil Cu and Zn levels in NZ are: i) total acid recoverable and ii) EDTA-extractable but the relationships of these two soil tests with soil UEA have not been explored. Therefore, this study is conducted to assess the relationship between common measures of soil Cu and Zn status and soil UEA of dairy-grazed pasture soils.

Materials and Methods

Twenty four dairy pasture soils (0-10 cm soil depth) from across the Waikato region with contrasting soil C, Cu and Zn status (Table 1) were used to measure the soil total acid recoverable and EDTA-extractable Cu and Zn levels, and soil UEA. Total acid recoverable Cu and Zn levels of soils were extracted following nitric/hydrochloric acid digestion procedure (Martin et al., 1994) and metals content of the extracts was measured by using Inductively Coupled Plasma Mass Spectrometer (ICP-MS). Soil extraction for EDTA-extractable soil Cu and Zn levels were performed by following the method as described by McLaren et al. (2005) and metals content of the extract was measured using Microwave Plasma Atomic Emission Spectrometer (MP-AES). Soil UEA was determined as the amount of urea hydrolysed (Zanuta & Bremner, 1975; Mulvaney & Bremner, 1979). Linear regression was performed to analyse the data using SAS 9.3 ($p < 0.05$).

Table 1: Soils characteristics of dairy-grazed pasture soils selected for analysis (S.N. with * indicates the exclusion of soil to measure EDTA-extractable metals because of insufficient soil for measurement)

S.N.	Soil order	Texture class	Soil pH	Soil total C (%)	Total Cu (mg kg^{-1} dry soil)	Total Zn (mg kg^{-1} dry soil)
1	podzol	sand	6.2	6.2	4.7	13.1
2	pumice	sand	5.7	7.8	5.4	30.0
3	brown	silt loam	6.3	3.7	8.6	58.0
4	pumice	sand	5.6	8.3	8.8	33.0
5	pumice	sand	5.8	7.2	8.8	22.0
6	allophanic	silt loam	6.2	10.8	16.0	90.0
7	gley	silt loam	5.9	10.7	16.0	42.0
8	allophanic	silt loam	6.1	7.3	16.4	73.0
9	gley	silt loam	6.0	9.4	21.0	56.0
10	recent	silt loam	6.0	5.8	23.0	85.0
11	allophanic	silt loam	6.4	9.2	24.0	120.0
12	gley	loam	5.6	6.7	29.0	125.0
13*	gley	silt loam	6.1	6.2	31.0	102.0
14	allophanic	silt loam	5.8	10.2	38.0	129.0
15	allophanic	loam	6.4	12.1	39.0	78.0
16	pumice	sand	5.8	6.0	5.6	19.3
17	allophanic	silt	5.5	18.7	15.0	28.0
18	gley	silt loam	6.1	7.9	14.1	43.0
19	gley	sandy loam	6.1	7.9	19.8	46.0
20	brown	silt loam	6.3	8.7	9.8	47.0
21	brown	silt loam	6.1	3.6	12.3	59.0
22	brown	silt loam	5.7	4.3	12.8	79.0
23	gley	clay loam	6.9	4.3	20.0	82.0
24	allophanic	silt	6.0	8.4	18.2	106.0

Results and Discussion

No significant negative correlations between soil Cu and Zn levels measured using either of two tests and soil UEA were observed (Figures 1, 2, 3 and 4). The lack of such a relationship could possibly be attributed to the inability of these tests to adequately represent their bioavailability for microorganisms and plants. Total acid recoverable measures all forms of Cu and Zn while most of it is organically bound with only a small proportion being immediately bioavailable. EDTA is supposed to extract potentially mobile portions of metal-ions in soil, including organically complexed metals, but also does not provide a direct measure of ionic forms that could potentially influence soil UEA. While the EDTA test may represent the bioavailability of these metals in soils with very low organic matter levels (McLaren et al, 1984) (e.g. tropical soils), in NZ dairy-grazed pasture soils with high organic matter much of the EDTA-extractable metals are likely to be organically complexed.

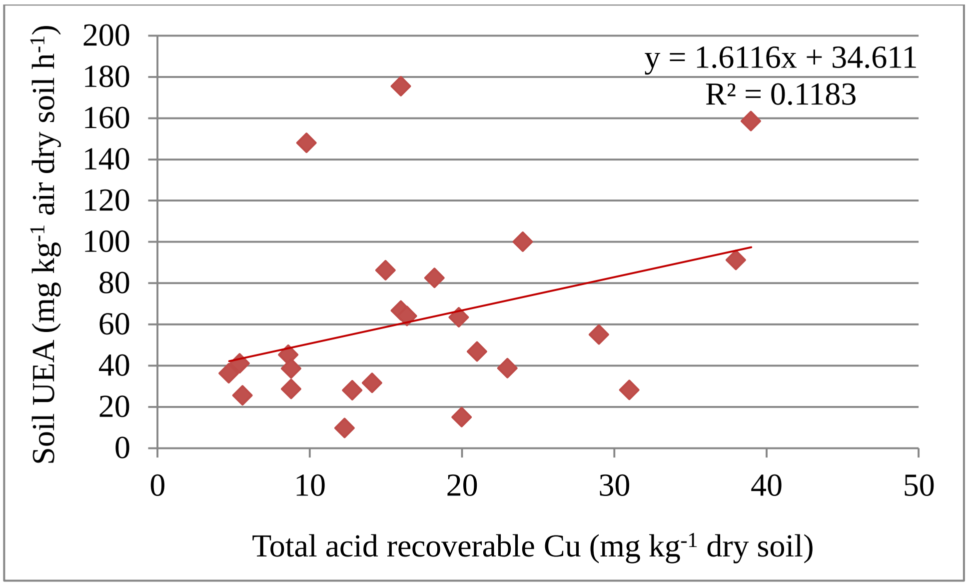

Figure 1: Relationship between total acid recoverable Cu and soil UEA of dairy-grazed pasture soils

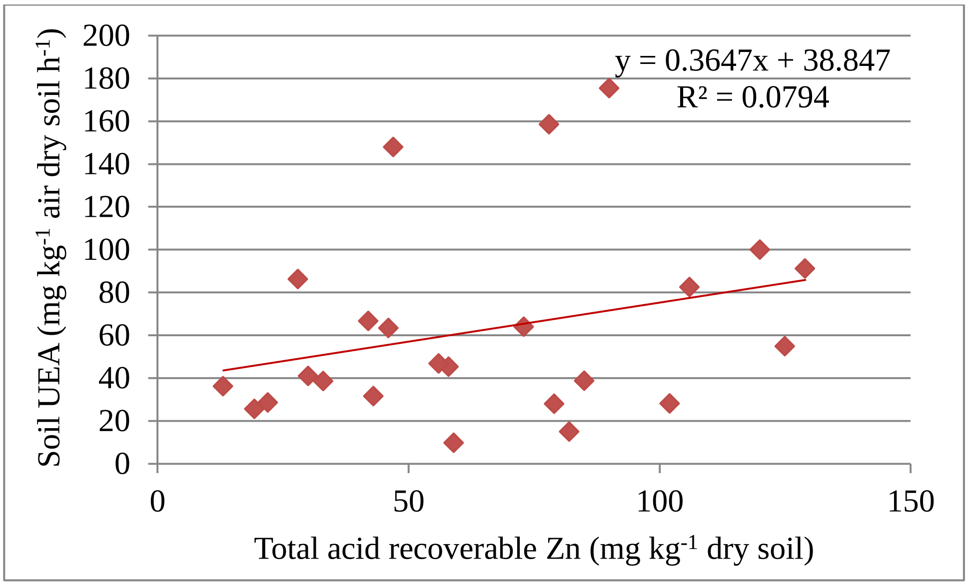

Figure 2: Relationship between total acid recoverable Zn and soil UEA of dairy-grazed pasture soils

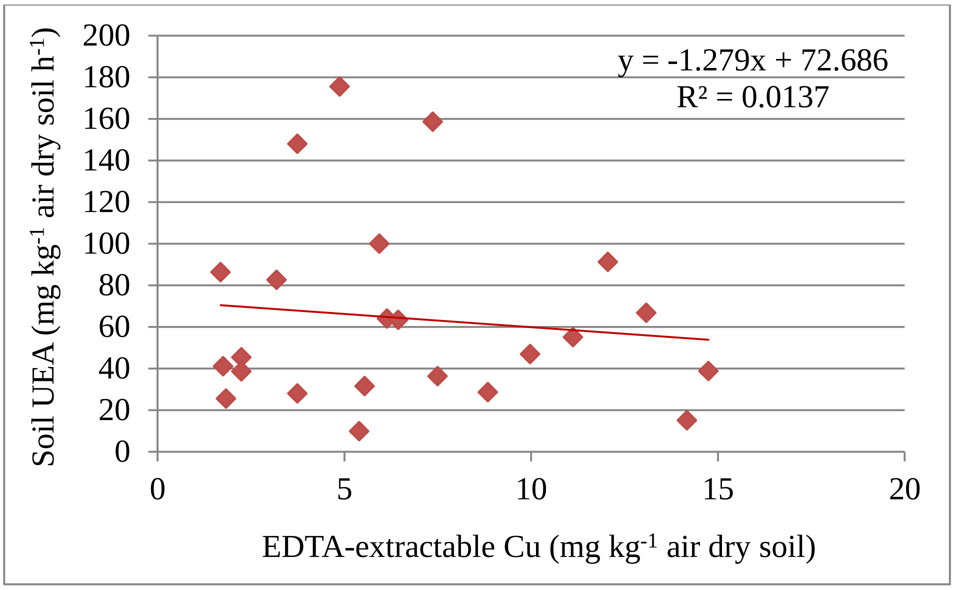

Figure 3: Relationship between EDTA-extractable Cu and soil UEA of dairy-grazed pasture soils

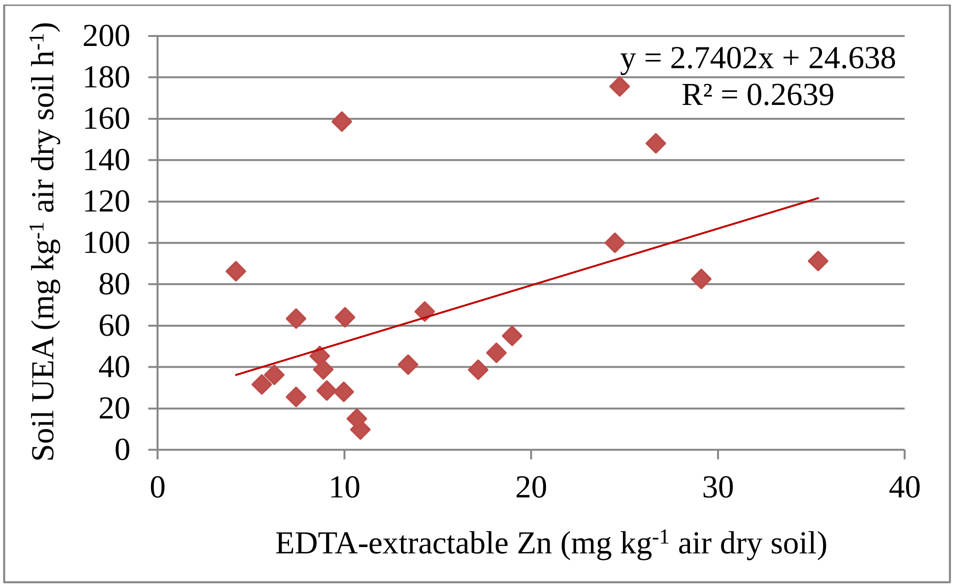

Figure 4: Relationship between EDTA-extractable Zn and soil UEA of dairy-grazed pasture soils

Soil total C levels showed significant positive correlation with soil UEA (Figure 5). Soil microbial biomass (SMB) normally constitutes between 1 to 2% of soil organic C levels in NZ pasture soils (Saggar et al., 1999) and the SMB increases with corresponding increase soil organic C. This relationship (Figure 5) could be attributed to higher microbial activity with increasing soil C levels. Microorganisms are considered as the primary source of soil enzymes. A wide range of microorganisms including bacteria, actinomycetes (filamentous bacteria), and fungi are able to hydrolyse urea intracellularly (Seneca et al., 1962). When enough C is available in the soil, the organisms grow, and as cells die, the release of urease enzyme occurs into the soil and become adsorbed on soil colloids. It is this extracellular urease that hydrolyses urea to ammonium (NH_4^+) ions.

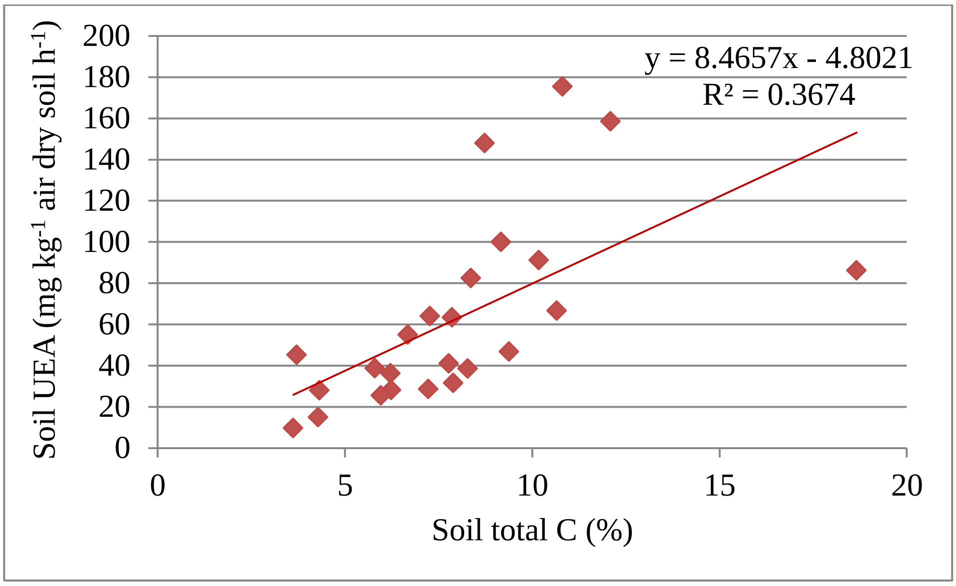

Figure 5: Relationship between soil total C level and soil UEA of dairy-grazed pasture soils

Conclusions and Future Work

The common methods of assessing soil status for Cu and Zn in NZ (total recoverable and EDTA-extractable), could not explain variations in UEA of the soils assessed. Future work will focus on identifying a suitable soil test to measure bioavailable Cu and Zn levels that potentially will allow relationships between soil UEA and Cu and Zn levels to be established.

Acknowledgements

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