Effectiveness of calcium nitrate in ameliorating soil acidity

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Calcium nitrate can be used to ameliorate soil acidity. However, its effectiveness is relying on sufficient root growth to uptake NO_3^- and release OH^-. Thus it is more effective in soils with low pH buffering capacity and moderate Al^{3+} level.

Introduction

Application of nitrogen (N) fertiliser in the form of nitrate (NO_3^-) can enhance anion uptake by plants and increase the pH of the rhizosphere soil via the release of OH^- ions. Root-induced alkalinisation of plant rhizospheres can ultimately increase that of the bulk soil providing there is sufficient root growth for the subsequent uptake of NO_3^- and release of OH^-. This study aimed to compare the effectiveness of calcium nitrate in ameliorating soil acidity in a range of acid soils with different soil pH, pH buffering capacity and Al^{3+} toxicity levels.

Experiment design

A soil column experiment was established with five acid soils from Frankston (Podosol), Rutherlgen (Chromosol), Holbrook (Chromosol), Cootamundra (Chromosol) and Welshpool (Chromosol) with different initial pH, pH buffering capacity and Al^{3+} toxicity levels (Table 1).

Soils were air-dried and sieved (<2 mm) and packed into PVC columns (10 cm diameter x 22 cm height, 2 kg of soil each). There were three N fertiliser treatments plus a nil fertiliser control: 1) urea, 2) calcium nitrate ($Ca(NO_3)_2$), and 3) slow-release potassium nitrate (KNO_3). All N fertilisers were applied at 60 mg N kg^{-1} soil in total, split into three applications: 30 mg N kg^{-1} at sowing and 15 mg N kg^{-1} at weeks 3 and 4.

The soil columns were wet to 90% field capacity, following the addition of basal nutrients, and allowed to stand in a controlled environment room at 25˚C. Ten pre-germinated wheat seeds (acid-tolerant line ET8) were sown evenly in each column. The seedlings were thinned to four at 12 days after sowing (DAS). Water was added every three days during the experiment. The columns were weighed each time before adding water. The soil within each pot was destructively harvested at 28 DAS. Shoots were cut off at the soil surface, washed with 0.1 M HCl and rinsed with Milli-Q water. Plant samples were dried at 70°C.

Soil from each pot was thoroughly mixed, subsampled and dried at 25°C. Soil pH was measured using a pH electrode after shaking end-over-end for 1 h in a 0.01 M solution of $CaCl_2$ (1:5 soil:solution), followed by centrifugation at 839 × *g* for 5 min. Monomeric aluminium (Al^{3+}) was determined using the pyrocatechol violet method in $CaCl_2$ extract.

Table 1 The pH, pH buffering capacity (pHBC) and extractble Al level of five acidic soils

Location	Soil type	pH (1:5 $CaCl_2$)	pHBC (mmol$^+$ kg^{-1} pH^{-1})	Extractable Al (mg kg^{-1})
Frankston, VIC	Podosol	4.5	7	N/A
Rutherglen, VIC	Chromosol	4.7	14	1.3
Holbrook, NSW	Chromosol	3.9	23	1.2
Cootamundra, NSW	Chromosol	3.9	23	9
Welshpool, VIC	Chromosol	4.0	50	30

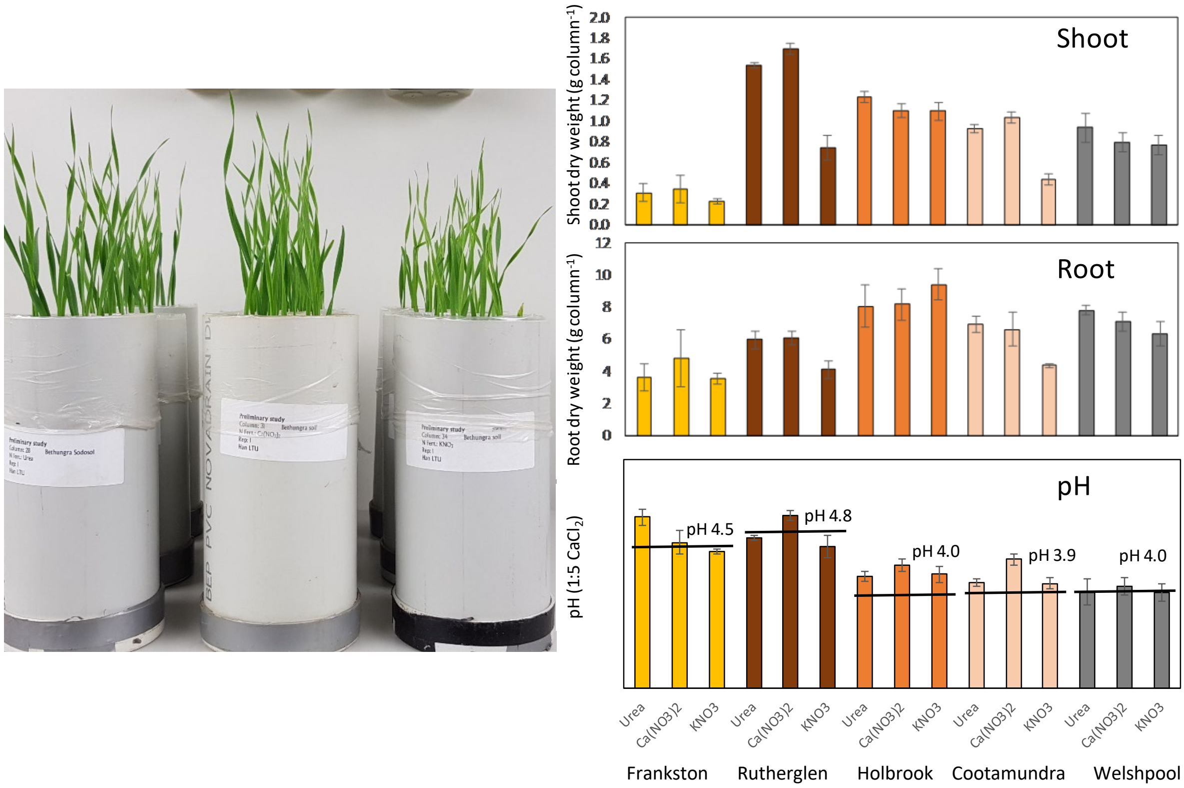

Figure 1. Dry weights of shoot (top) and bulk soil pH (bottom) for soil treated with urea, $Ca(NO_3)_2$ and slow release KNO_3. Black solid lines indicate initial soil pH. Bars indicate ±standard errors (n=3).

Results

Increases in shoot growth were associated with increased soil pH (Figure 1). Bulk soil pH increased significantly with the $Ca(NO_3)_2$-treated soils at Rutherglen and Cootamundra with low pH buffering capacity and moderate Al^{3+} content (Table 1). Soil treated with slow-release KNO_3 yielded the lowest shoot biomass compared with $Ca(NO_3)_2$ or urea in all soils. $Ca(NO_3)_2$ and urea had no effect on root weight in all soils. However, root biomass was lower in soil treated with slow release KNO_3 compared with that treated with $Ca(NO_3)_2$ and urea for the Rutherglen and Cootamundra soils.

The form of N controls the cation-anion balance which facilitates NO_3^- (anion) or NH_4^+ (cation) uptake and consequent changes in rhizosphere pH. The nitrate treatments could lead to excess uptake of anions over cations by plants. Furthermore, greater shoot growth in the nitrate treatment may have also contributed to greater nitrate uptake and consequently greater alkalization. Effectiveness of this biological manipulation relies on root function not being impaired, nor plant growth limited by nutrient availability or aluminium toxicity, which may occur in acid soils.

Conclusions

Calcium nitrate is likely to be effective in moderately acidic soils with low pH buffering capacity that would allow sufficient root development. Slow-release KNO_3 alone did not meet the N requirement of wheat at an early stage, which limited root growth.

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