Data Article

Data validating the use of rubidium as a non-radioactive tracer for the localised proliferation of wheat roots in acidic or limed subsoil

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\textbf{A B S T R A C T}

Existing technologies for lime (\textit{CaCO}_3) incorporation into acidic field soils result in the heterogeneous distribution of limed and acidic soil sections. In a study characterising the response of wheat (\textit{Triticum aestivum} L.) to the amendment of an acidic soil profile with vertically limed slots \cite{1}, elucidation of the dynamics of root proliferation within the acidic and limed soil sections was a prerequisite to understanding the mechanisms driving the above-ground responses. Rubidium (Rb) has been used widely as a non-radioactive tracer for root activity \cite{2} in soil. However, the contrasting pH in a heterogeneous limed soil profile and related aluminium toxicity effects to roots can influence the availability and uptake of Rb, and quantitative data relating Rb uptake to root phenology in this scenario are lacking. To validate the use of Rb as a tracer for root activity within vertically limed slots in an acidic soil profile, its uptake by wheat roots from acidic or limed sections of subsoil, and its relation to root architecture was assessed.
Wheat plants were grown in a glasshouse in 29 cm deep, vertically split soil columns with acidic (pH 3.9), Al-toxic subsoil on one side and the same soil amended with lime on the other side. Rubidium chloride was applied at 5, 10 or 20 mg Rb kg⁻¹ to either limed or acidic soil sections. Wheat plants were grown for 28 days, after which the Rb content in shoots and the root length and diameter in each of the discrete soil sections was measured.

Foremost, the Rb amendments (5, 10 or 20 mg Rb kg⁻¹ soil) did not induce any toxic effects; shoot dry weight and root length in the limed and acidic sections of the subsoil were not statistically different among the rubidium-amended and non-amended treatments, regardless of its placement (limed vs. acidic sections). Average root lengths in the limed sections of the subsoil (69.5 m section⁻¹) were approximately 10-fold greater than in the acidic sections (6.3 m section⁻¹). Likewise, the concentration of Rb in shoots was, on average, 7-fold greater where Rb was applied to the limed (vs. acidic) subsoil section and was positively influenced by the rate of Rb amendment in the limed (p ≤ 0.05), but not the acidic section of the subsoil. Rubidium uptake into shoots was significantly correlated (p ≤ 0.05) with the length of roots within the Rb-amended subsoil section. The uptake of Rb from acidic or limed subsoil sections was determined by the root length in the Rb-amended subsoil section, regardless of the rate of Rb amendment. The uptake of Rb per unit of root length from acidic or limed sections of subsoil was not significantly different.

The data validate the use of Rb as a tracer for the dynamics of root length proliferation in limed subsoil sections in a heterogeneously limed acidic soil profile.

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Specifications Table

| Subject                        | Soil Science                  |
|-------------------------------|-------------------------------|
| Specific subject area         | The data validates the use of Rb as a non-radioactive tracer for localised root proliferation within discrete soil sections of heterogeneously limed acidic soil profiles. |
| Type of data                  | Figure                        |
| How the data were acquired    | Shoot and root mass data were acquired by gravimetric analysis, root length data from image analysis of plant roots (WinRHIZO, Regent Instruments, Quebec, Canada), Rb and K content by Inductively coupled plasma mass spectrometry (Nexion 1000, Perkin Elmer, USA), soil solution pH by Orion™ 815600 ROSS™ Combination pH Electrode and an Orion Star™ A111 pH Benchtop Meter (Thermo Fisher Scientific, MA, USA). |
| Data format                   | Analysed, Raw                 |
| Description of data collection| Wheat (Triticum aestivum L.) plants were grown in vertically split soil columns (one half acidic subsoil and the other half limed subsoil). Plants were grown in a glasshouse for 28 days. The dry mass and Rb and K concentration of the wheat shoots was measured. Wheat roots from the acidic or limed subsoil sections were washed free of soil and analysed for length and diameter. |

(continued on next page)
Value of the Data

• The data validate the use of Rb as a non-radioactive tracer for the localised proliferation and activity of roots in acidic or limed soil sections [1] by demonstrating the quantitative relationship between Rb accumulation in shoots and root length in Rb-amended sections of subsoil, regardless of the lime amendment (Fig. 1).
• The data can be extended to other studies as a quantitative or qualitative methodology to characterise the spatial and temporal dynamics of root proliferation and root activity within various soil sections of heterogeneously limed acidic soil profiles.
• The data will enable researchers studying the interactions of plant roots with heterogeneous soil environments by facilitating the application of the Rb tracer to characterise root system development and activity [2].

1. Data Description

Although Rb has been used as a tracer for root activity in soil [2], its use in heterogeneously limed, acidic soil profiles has not been validated [1]. The data firstly assess shoot growth and root growth responses to the labelling of the limed or non-amended sections of an acidic, Al toxic subsoil with a low (5 mg kg\(^{-1}\)), moderate (10 mg kg\(^{-1}\)) or high (20 mg kg\(^{-1}\)) rate of Rb (Table 1). Secondly, the data relate the Rb uptake from the discrete sections of limed or acidic subsoil by young wheat plants (Fig. 1) to root length and morphology within the Rb amended section of subsoil (Fig. 2; Fig. 3).

2. Experimental Design, Materials and Methods

2.1. Experimental setup

Bottom-sealed, cylindrical, PVC columns; 15 cm diameter and 30 cm deep, with a vertical divider from 5 to 30 cm depth were used. Acidic subsoil was placed on one side of the divider, and limed subsoil was placed on the other side, and a 4 cm layer of acidic topsoil was placed above the split subsoil layer (Fig. 1) as described below.

Acidic topsoil and subsoil were collected from 0–10 cm depth and 20–40 cm depth, respectively, of a naturally acidic soil profile (Profundic Lixisol [3]) near Kalannie, Western Australia (30.367° S, 117.121° E), which had been used for crop production. The acidic topsoil and subsoil were each air-dried, sieved to remove the ≥4 mm fraction, and thoroughly mixed for uniformity. The topsoil had a pH (in CaCl\(_2\)) of 4.1 and exchangeable Al, Ca, K, Mg and Na (in cmolc kg\(^{-1}\)) of 0.15, 0.93, 0.15, 0.25 and 0.08, respectively. The subsoil had a pH (in CaCl\(_2\)) of 3.9 and exchangeable Al, Ca, K, Mg and Na (in cmolc kg\(^{-1}\)) of 0.65, 0.14, 0.04, 0.04 and 0.02, respectively. Limed subsoil was prepared by thoroughly mixing limesand (99% less than 0.5 mm and 95% neutralising value) with half of the acidic subsoil at a rate of 0.59 g kg\(^{-1}\) soil.
Fig. 1. The split column set-up for assessing the uptake of rubidium (Rb) from an acidic or lime (CaCO₃)-amended subsoil. Acidic, sandy subsoil was placed on one side of a 25 cm deep, 15 cm wide plastic barrier and the same subsoil amended with lime on the other side. Rubidium chloride was applied to either the acidic or limed subsoil section at rates of 5, 10 or 20 mg Rb kg⁻¹ soil. The subsoil was overlain with a 4 cm deep layer of acidic, sandy topsoil. Wheat (*Triticum aestivum* L. cv. Mace) plants were grown in a 10 cm long row positioned above, and oriented in line with, the plastic barrier in the underlying subsoil.

2.2. Experimental design

There were seven treatments whereby rubidium chloride (RbCl) was mixed through the acidic or limed subsoil sections: (i) an untreated control (no Rb applied), rubidium chloride (RbCl) mixed through the untreated, acidic subsoil at (ii) 5, (iii) 10 or (iv) 20 mg Rb kg⁻¹, and RbCl mixed through the limed subsoil at (v) 5, (vi) 10 or (vii) 20 mg Rb kg⁻¹. The experiment was conducted in triplicate and arranged in a randomised complete block design.

2.3. Methods

1. The amended and non-amended soils were wet to field capacity water content (13% v/v) and placed into respective sections of the pots to a depth of 25 cm. Dry topsoil was then placed into pots above the subsoil to a depth of 4 cm, giving a total soil depth of 29 cm (Fig. 1) and sufficient deionised water was applied to the soil surface to bring the topsoil to field capacity water content (13% v/v).
Table 1
Shoot dry weight, shoot Rb concentration, shoot K concentration, and root length in limed and acidic subsoil sections for 28-day-old wheat (cv. Mace). Plants were grown in 29 cm deep, vertically split soil columns with half of the acidic subsoil amended with lime, and the other half not limed (see Figure 1). Rubidium chloride was applied to either the limed section or acidic section of the subsoil at a rate of 5, 10 or 20 mg Rb kg⁻¹ soil, or was not applied (Control). Values in parentheses are standard errors of means (n=3). Letters denote significant differences among means (α=0.05). Absence of letters indicates no significant difference among means.

|                                | Not Rb amended | Rb applied to limed section | Rb applied to acidic section |
|--------------------------------|----------------|----------------------------|-----------------------------|
| Shoot dry weight (g pot⁻¹)     | 1.27           | 1.25                       | 1.28                        |
| Root length in limed soil section (m) | 63.9           | (6.2)                      | 70.6                        |
| Root length in acidic soil section (m) | 5.02           | (0.51)                     | 7.60                        |
| Rb concentration in shoots (mg g⁻¹) | 0.07a          | 1.55b                      | 6.40d                       |
| K concentration in shoots (mg g⁻¹) | 40.9           | (11)                       | 39.8                        |

Fig. 2. The relationship between the relative uptake of Rb from acidic or limed soil sections and root length in the respective soil sections. Wheat plants were grown in 29 cm deep, vertically split soil columns with half of the acidic subsoil amended with lime, and the other half not limed (see Figure 1). Rubidium chloride was applied to either the limed section or acidic section of the subsoil at a rate of 5, 10 or 20 mg Rb kg⁻¹ soil, or was not applied (Control). Relative uptake of Rb was calculated as the amount of Rb accumulated in shoots as a proportion of the amount of Rb applied to soil. Values grouped near the axes are from the acidic soil sections.

2. The constructed soil profiles were incubated for 1 week at 20 °C to allow equilibration of the lime and Rb treatments with soil. Mono-ammonium phosphate fertiliser granules (CSBP Ltd., Kwinana, Western Australia) were applied to the topsoil positioned above, and oriented in line with, the plastic barrier at a depth of 3.5 cm and a rate of 180 mg pot⁻¹ (equivalent to 11 kg N ha⁻¹ & 22 kg P ha⁻¹). Wheat (Triticum aestivum L. cv. Mace) seeds (6 pot⁻¹) were sown above the fertiliser band at a depth of 1.5 cm. Wheat plants were thinned to three average-sized seedlings 1 week after sowing. Soil water content was assessed gravimetrically and maintained near field capacity by watering with de-ionised water every 2 days. The experiment was conducted in a naturally lit glasshouse at a controlled temperature of 20.0/15.0 °C (day/night) at The University of Western Australia, Crawley, Western Australia (31.950° S, 115.860° E).

3. The experiment was terminated 28 days after sowing by cutting shoots at the soil surface, drying at 65 °C and the weight recorded.
4. Dry shoots were digested in HNO₃/HClO₄ acids [4]. Briefly, 0.2 g of finely ground plant material was weighed into a 25 ml Erlenmeyer flask, 5 mL of c.HNO₃ was dispensed into each flask and the solution was heated at 100 °C in a purpose-built fume hood with air scrubbers until the reaction ceased and no undissolved plant material remained. After cooling, 0.5 mL of c.HClO₄ was dispensed into each flask and the solution was slowly heated to 150 °C, maintained at 150 °C for 2 h until only 0.5 mL of c.HClO₄ remained, then at 160 °C for a further 10 min. After cooling, the acid digest solution was transferred into a calibrated vial and the volume made up to 10 mL with double deionised water. Solutions were analysed for K and Rb concentration by ICP-MS (Nexion 1000, Perkin Elmer, USA). The K and Rb content in shoots were calculated as the product of their concentration and shoot dry weight.

5. Roots were collected from each of the soil sections (topsoil, acidic subsoil and limed subsoil) by washing soil from roots with running water over a 2 mm sieve. Roots were stored and stained in a solution containing ethanol (50% v v⁻¹) and black Parker Quink (5 mL L⁻¹) for 2 weeks and analysed for length and diameter using the WinRHIZO root analysis system (Regent Instruments, Quebec, Canada) with an Epson Perfection V800 tracking scanner. Root images were analysed in 8-bit greyscale, at 400 dpi resolution, using ‘intrinsic’ calibration and threshold set to ‘auto’.

2.4. Statistical analysis

Shoot data were subjected to 1-way ANOVA for main treatment effects and 2-way ANOVA for Rb rate*placement interactions for root length and root surface area. Comparison of mean values was done by the Tukey’s t-test at the 5% confidence interval (Genstat 20th Edition; VSN International, Hertfordshire, UK).
Ethics Statements

The study complied with all applicable codes of ethics.

CRediT Author Statement

**Paul Damon:** Conceptualization, Investigation, Writing - original draft; **Gaus Azam:** Conceptualization, Project administration; **Chris Gazey:** Conceptualization, Funding acquisition; **Craig A. Scanlan:** Conceptualization and **Zed Rengel:** Conceptualization, Writing - review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Vivian Lis Piñero and Michael Smirk conducted root length and elemental analyses, respectively. Robert Creasy and Bill Piasini managed the plant growth facilities. All are from the Faculty of Science, The University of Western Australia.

Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.dib.2022.107868.

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