SOIL CRC
Performance through collaboration

RESEARCH FINDINGS
FACT SHEET

MORE PROFITABLE CROPS ON HIGHLY CALCAREOUS SOILS BY IMPROVING VIGOUR AND OVERCOMING SOIL CONSTRAINTS

Project 4.2.003

KEY POINTS

- Highly calcareous soils impose multiple constraints that limit early crop growth and overall productivity.
- Improving early crop vigour through higher seeding rates and targeted fertiliser at sowing consistently increased biomass and grain yield.
- Short-term topsoil strategies were more reliable than subsoil interventions, which showed delayed and less consistent responses. High soil strength is an issue in calcareous soils, however, positive responses to deep ripping are less likely and usually limited by the hostile subsoil.
- Carbon-coated mineral (an engineered biochar-based product) applied near the seed improved crop establishment and yield, and provided benefits to subsequent crops.
- Iron deficiency is a constraint for pulses on calcareous soils. Iron chelates stable under high pH corrected deficiency and significantly increased broad bean yield.

Benefit of phosphoric acid to barley production on a highly calcareous sand at Port Kenny (South Australia) in 2022. Plot at centre left is district practice (granular Mono-Ammonium Phosphate [MAP] as the source of phosphorus at seeding), plot at centre right was treated with phosphoric acid as the phosphorus source at seeding.

Calcareous soils project team, (from left to right) Ian Richter, Nigel Wilhelm, John Kirkegaard and Brian Dzoma at the calcareous soil profile at the Minnipa trial site in 2021.

THE CHALLENGE

Calcareous soils are widespread across south-eastern Australia, occupying 60% of the cropping soils in the region. They present multiple constraints to crop production, including low phosphorus availability, poor nitrogen cycling, low water-holding capacity, and high levels of rhizoctonia. Crops may also be affected by fertiliser toxicity during germination, extreme pH, sodicity and salinity. These constraints can severely limit early crop growth and overall productivity.

This project focused on identifying practical approaches to improve soil condition, early crop vigour, and crop productivity on calcareous soil in the south-east and upper Eyre Peninsula of South Australia.

OUR RESEARCH

Controlled environment studies

Controlled environment studies were used to better understand carbon processes in calcareous soils. This work examined:

- how phosphorus fertilisers (diammonium phosphate, liquid phosphoric acid, and biochar-blended phosphorus) influence carbon cycling
- how soil amendments (goethite and biochar) influence the stability and decomposition of labile carbon in calcareous subsoil
- if adding iron-oxides can help hold carbon in the soil for longer, including carbon released by plant roots.

A range of materials were also investigated for their ability to stabilise soil organic carbon (SOC) and improve nutrient cycling, availability and soil stability. This work identified a carbon-coated mineral as a promising amendment, which was subsequently included in the field trials.

Field trials

Six field trials ran from 2021–2023 on the upper Eyre Peninsula under commercial farming conditions. Four of these trials were located on highly calcareous grey sandy soils (at Poochera and Port Kenny) and the other two on a red calcareous sandy loam (at Minnipa).

Three trials investigated long-term subsoil improvement strategies, while the other three investigated short-term topsoil strategies to improve early crop establishment and productivity. Treatments included fertilisers, fungicides, deep ripping, a carbon-coated mineral engineered by the NSW Department of Primary Industries and Regional Development (DPIRD), wetting agents and organic matter.

Broad bean studies

Field trials at Lake Hawdon in south-east South Australia (2021 and 2022) and glasshouse trials in 2023 investigated iron and manganese deficiencies in broad beans on highly calcareous soils. These deficiencies commonly cause yellowing and poor early growth under cold, wet winter conditions.

The trials compared different ways of supplying iron and manganese to the crop, including seed coatings, fertiliser at sowing, and foliar applications, as well as different fertiliser forms such as chelates and sulphates. These approaches were tested against standard district practice (in-season foliar applications once yellowing is apparent) to determine if alternative iron and manganese application strategies could prevent deficiency symptoms and improve crop production.

RESEARCH FINDINGS

Controlled environment studies

Phosphorus fertiliser placement influenced carbon dynamics in calcareous soils. Broadcasting phosphorus fertiliser increased carbon losses from both:

- soil organic carbon and soil inorganic carbon in non-rooting zones (i.e. not near crop roots)
- carbon released by plant roots.

In contrast, phosphorus stabilised existing SOC in the root zone, indicating that placing phosphorus fertiliser close to plant roots is more effective for retaining carbon in highly calcareous soils.

Iron-based amendments helped stabilise carbon. Goethite reduced the loss of easily decomposed (labile) carbon, while iron oxides increased stabilisation of both soil-derived and plant-derived carbon. However, iron oxide application was also accompanied by increased carbon dioxide loss from soil carbonates.

Biochar increased the breakdown of plant material (lucerne stubble) but also improved how efficiently this carbon was retained in the soil.

Together, these results highlight the potential for iron-based amendments and biochar to improve soil carbon storage in calcareous soils.

Upper Eyre Peninsula field trials

High soil strength is a constraint in calcareous soils. However, positive responses to deep ripping were inconsistent and often limited by the hostile subsoil. For example, by 2023 there were signs of re-compaction in ripped treatments, with penetration resistance slightly higher than initial measurements taken in 2021.

Short-term topsoil strategies which focused on improving early crop establishment and vigour consistently outperformed longer-term subsoil approaches. Increasing seeding rates, supported by adequate nutrition including nitrogen, phosphorus and trace elements, improved plant establishment, biomass and grain yield.

Subsoil amendments aimed at improving fertility (fertiliser, organic matter) showed some potential to increase yield on highly calcareous soils. However, responses were delayed and only became evident in the third season. Their economic value remains uncertain.

Applying the carbon-coated mineral just below the seed improved crop vigour, biomass and yield (Figure 1). This was attributed to the superior delivery of phosphorus to the crop compared to conventional fertilisers. Benefits were also observed in the following crop, indicating some carryover effect.

South-east South Australia trials (broad beans)

The field and controlled environment studies showed that yellowing in broad beans grown on highly calcareous soils is primarily caused by iron deficiency, with little evidence of manganese deficiency.

Standard district practice of multiple foliar applications of iron and manganese sulphates, or EDTA chelates had limited effect on crop condition. In contrast, applications of iron in a chelated form stable under high pH (iron-EDDHA) corrected deficiency symptoms and led to substantial increases in crop growth and yield (Figure 2).

A controlled environment system was developed that reliably reproduces iron deficiency in pulses on the Lake Hawdon soil. This system enables faster and more targeted testing of iron sources, rates, formulations and application strategies than can be achieved through field trials alone.

SIGNIFICANCE OF THE FINDINGS

These findings indicate that improving early crop vigour is a reliable pathway to increasing productivity on highly calcareous soils. In contrast, subsoil interventions are higher risk and less predictable. Constraints at depth are difficult to overcome, and practices such as deep ripping may not deliver sustained benefits due to re-compaction and hostile subsoil conditions. This has important implications for grower investment decisions, where upfront costs are high but returns may be uncertain.

Identifying the carbon-coated mineral as a promising amendment provides a potential new tool for improving crop performance on calcareous soils. However, further work is needed to confirm its consistency, optimal application (rate, location, timing) and economic viability.

The growth and yield of broad beans growing on highly calcareous clay-loams of the south-east of South Australia can be greatly improved with applications of iron-EDDHA. However, this product is very expensive for broadacre farmers. Further investigations are required to test the effectiveness of reduced rates of iron-EDDHA, to develop more effective application strategies or to find alternative (and effective) sources of iron before an economically attractive package can be recommended to growers and advisers in the region.

Figure 1. Better crop growth and vigour from carbon-coated minerals at 500 kg/ha. Minnipa, 18 August 2021.

Figure 2. Response of broad beans to chelated iron applications at Lake Hawdon, 2022. Left hand plot: typical practice of repeated applications of iron-sulphate, right hand plot: multiple applications of iron-EDDHA.

The controlled environment studies provide new insight into how carbon behaves in calcareous soils, particularly the role of iron-based amendments in stabilising soil organic carbon. This improves our understanding of how these soils function and identifies potential pathways to re-engineer hostile subsoils and increase carbon storage.

The development of a reliable controlled environment system to reproduce iron deficiency is also significant, as it enables faster and more targeted testing of fertiliser strategies than field trials alone. This will support more efficient development of management practices for calcareous soils.

NEXT STEPS

The project 'Improving crop phosphorus supply on highly calcareous soils' (4.2.007) is examining the importance of the phosphorus component in the carbon-coated mineral to improve phosphorus delivery to plants, and investigate if other types of biochar provide similar benefits to crops.

Further research is needed to determine practical carbon-coated mineral application protocols for broadacre farming, such as optimal placement methods and minimum effective rates. Research is also needed to quantify the impact of the carbon-coated minerals on farm profitability under commercial conditions. The carbon-coated mineral has demonstrated strong agronomic potential in research trials but is not yet commercially available.

Further work is also required to improve the practicality of correcting iron deficiency in broadacre systems. This includes refining application methods, reducing costs of iron chelates, and identifying alternative iron sources suitable for high pH soils.

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This fact sheet and related project publications are available on the Soil CRC Knowledge Hub (soilcrc.com.au/resources)

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