Soil Acidity Management in Western Australia - an integrated project

Summary
Soil acidity is now recognised as one of the, if not the biggest, soil degradation factors facing broadacre farming in Australia. In particular, the National Land and Water Audit, in its publication 'Agriculture Assessment 2001' identified Western Australia (WA) as having 4.8 million ha with a pH below 5.5 in the subsurface being second only to New South Wales (NSW) in terms of the area affected. Soil acidity has the potential to reduce production and the profitability of broadacre farming in WA. In extreme cases, it restricts the cropping options available to growers and reduces their ability to address other significant issues such as groundwater use and rotations for weed control. In less extreme cases, the losses to production can be in the order of 10%-20%. Estimates for WA's requirement for agricultural lime to treat soil acidity vary between 1-2 million t/yr.

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Conclusions
The major conclusions from this project are that:

- Ongoing soil acidification in the WA wheatbelt is a significant threat to agricultural production.
- Acidic soils in the wheatbelt of WA can be economically treated via the application of lime to treat soil pH. This is possible because of a combination of factors:
  i) WA is fortunate to have large reserves of good quality, relatively cheap limesand and limestone.
  ii) Most of WA's soils affected by low pH also have low buffering capacity which means that relative to soils in the eastern states, low rates of lime application are sufficient to treat low soil pH.
  iii) Responses to the treatment of acidic soils are generally positive and can be demonstrated.
- The biggest contributor to the quality of lime and therefore its effectiveness under WA conditions is particle size rather than lime type.
- The topsoil pH needs to be maintained at or above pH 5.5 (CaCl₂) for sufficient movement of alkalinity down the soil profile to treat subsurface acidity in the 10-30cm layer from surface applied lime.
- Current rates and frequency of surface application of lime are generally insufficient to adequately treat sub-surface acidity.
- Soil samples be taken to determine the current soil pH down the soil profile so that appropriate management plans can be developed and that following the introduction of a liming program, both soil and plant tissue tests be taken on a regular basis to monitor the effectiveness of the lime in the soil, while the plant tissue analyses can be used to identify any modifications in fertiliser use which may be necessary following a change in the soil conditions.
- The inclusion of crop species or varieties which show greater tolerance to aluminium (Al) (which can occur in toxic quantities in low pH soil in WA) can provide a useful addition to the management of acidic soils by allowing production to be obtained while the liming program is being commenced and the lime is beginning to have an effect on the soil profile over the first few years. It is noted that the use of Al tolerant varieties is not a solution and should be used in conjunction with a liming program.
- The lime industry in WA has developed a voluntary code of practice with the support of project staff, mainly from the associated National Heritage Trust (NHT), project but also supported technically by many staff employed on this project at the University of WA (UWA) and the Department of Agriculture WA (DAWA).
- Nitrate leaching beyond the root zone is a significant contributor to the acidification of soils and that the use of lucerne-based pastures in place of annual-based pastures is promoted to reduce rates of acidification by reducing the amount of leakage and nitrate leaching.

Recommendations
That information about the appropriate management of soil acidification be freely available and that recommendations on the use of liming products to treat acidity generated as a result of productive agriculture be promoted by all members of the agricultural industry, including Departmental development officers and research officers, fertiliser industry representatives
and agricultural advisers.

Such information includes the:

- Promotion of information which raises awareness of soil acidification as an inevitable outcome of productive agriculture which needs addressing in the same way as nutrient removal is addressed by the application of fertiliser.
- Promotion of soil testing, including depths below 10cm in order that growers are aware of their current soil conditions with respect to pH.
- Promotion of information to enable growers to make a 'value for money (VFM)' choice on which lime product to purchase. This includes support for the lime industry and suppliers in WA who follow a voluntary code of practice.
- Critical soil pH values - aim to maintain a topsoil pH above 5.5 and a subsurface above 5.0 in most circumstances to avoid potential losses from sub-surface acidity.
- Promotion of the benefits of maintaining the appropriate soil pH which include the ability of growers to be able to choose from a wider selection of crop and pasture species rather than being restricted to a few very acid tolerant species, and more effective use of fertilisers.

Outcomes

Expected Outcome (benefits)

Economic Outcomes

The following text is taken from the summary of 'Benefit-Cost Analysis of Soil Acidity Research Development and Extension in WA 1992-93 to 2001-02' Miscellaneous Publication 26/2003 by M. O'Connell and C. Gazey. The full publication is submitted with this report (Attachment 1).

The program of publicly funded soil acidity RD&E conducted in WA from 1992-93 to 2001-02 has already delivered net benefits to growers. These benefits are expected to increase substantially over future years. Benefit cost analysis indicates that these industry benefits should outweigh the public cost of the RD&E several times over.

Using a 20 year analysis period, the RD&E is estimated to have a net present value (NPV) of $84million, and a benefit cost ratio (BCR) of 5.8. Extending the analysis to 30 years results in an NPV of $135million and a BCR of 8.7. These large returns are due to a combination of factors:

- The high uptake of liming by growers since the commencement of intensive RD&E in the mid-1990s.
- The long term benefits that liming provides to crops and pastures.
- The relatively low costs of applying lime.

The actual value of the RD&E is sensitive to several assumptions about which there is uncertainty. Despite this, the RD&E is expected to deliver a net benefit under most scenarios examined. There is a high degree of confidence in this conclusion due to the fact that a high uptake of adoption has already occurred, thereby locking in future benefits.

In addition to the future benefits that are already locked in, the analysis highlights considerable upside potential that could be realised by future projects through R&D on methods that further increase the profitability of managing soil acidity.

Environmental Outcomes

This project was aimed at increasing the understanding and management of soil acidity in WA. Since 1994/1995 annual lime use has increased by more than a factor of five. The use of lime to treat soil acidity is the most effective strategy so an increase in adoption of liming from approx. 150,000t/yr to more than 800,000t/yr in 2001/2002 is a marked success for this project and the lime industry in WA. Over that period which covers part of the previous soil acidity project, a total of 3.68 million tonnes of lime has been spread. Most of this has been at an average of 1.1t/ha and again most have been first time applications. While this is a significant achievement, the quantity being used still falls below even conservative estimates of what is required to treat existing and ongoing soil acidification in the WA wheatbelt. On-going efforts are required not only to monitor but also to encourage and support the continued adoption of liming in WA.

(Lime use figures quoted have been sourced on an annual basis from the ABS).

Social Outcomes
While not directly part of this project and no actual measurements have been made, the increase in the use of lime in WA has meant the development of a much bigger liming industry than was previously operating. The transportation of large quantities of lime primarily from the West Coast east into the wheatbelt must have had an impact on employment for truck drivers, lime spreaders and support industry.

Achievements/Benefits

Overview of Project Achievements

This project was aimed at developing an understanding of the issues surrounding the management of soil acidity in WA providing best management practice (BMP) information, particularly with respect to subsurface acidity to growers and agribusiness and monitoring the implementation of the recommended management techniques and adjusting them where necessary.

Lime use is the single most measurable parameter to monitor the management of soil acidity. Other measures such as monitoring the change in pH over time are both time consuming and expensive or open to interpretation where surveys are used over a short timeframe. This project, with the support of the DAWA commissioned the Australian Bureau of Statistics (ABS) to collect figures on agricultural lime use on an annual basis from 1994/1995 to the present.

In the three years prior to the start of this project (1994-1996), the use of agricultural lime in WA averaged 220,000t per year by 1,500 growers. By the end of this project, lime use had increased to a record of 825,000t in 2002 and averaged 600,000t per year for the five years (1997-2002) by 2,840 growers. This figure still falls short of the estimated 1-2 million t/yr but is a tremendous achievement in terms of changing farming practices. There was a noticeable drop in lime use in 2000 and 2001 following years of poor production due to low rainfall. The fact that lime use increased in 2002 indicates that a change in practice has occurred. While not all of the credit for this success can be claimed directly by the project, there is no doubt that the information generated and provided to industry was a major catalyst. This area of attribution is discussed in the published Benefit Cost Analysis of Soil Acidity Research Development and Extension in WA 1992-93 to 2001-02 (O’Connell & Gazey, 2003) attached to this report (Attachment 1).

This GRDC integrated soil acidity project in conjunction with the NHT funded project (983206) ‘Developing Industry Ownership & Management of Soil Acidification’ has generated a lasting set of soil acidity resource material which remains in high demand. At the forefront is a set of Soil Acidity Research Development and Extension Update bulletins that were produced by the project on an annual basis (1997-2002). The six bulletins presented the current research results and recommendations from each of the sub-projects each year. Many articles cover the development of the lime industry which received support from all areas of the project during its development. A major achievement in the project was to ensure that detailed process research conducted mainly at UWA produced outputs and information that was relevant and could be practically adopted by growers. One way that this was achieved was through the ongoing development of the ‘Optlime’ model. ‘Optlime’, an Excel based, bioeconomic model of soil acidity management required the development of information specific to WA on aspects of lime quality, pH change in soil and effects of pH on Al levels under WA conditions, crop response to soil conditions and an economic analysis. The development of the model acted as a communication tool, as it allowed identification of gaps in information or knowledge and provided each area of endeavour with a sense of belonging in the project. The model has been released as an educational tool to aid in the understanding of soil acidity management, but should not be used to provide advice on rates of lime that should be applied in a particular circumstance. General rules of thumb generated and refined during the project are sufficient given the large degree of variability in both soil type and conditions within paddocks.

Integrating the NHT extension project with the GRDC Research and Development (R&D) project and the media consultancy ensured that there was no delay in transfer of new knowledge and information to the end users, be they growers or advisers. Staff in the project worked at a range of levels from detailed to very applied. A focus of work was to use large scale grower managed replicated demonstration sites. This approach meant that problems that potentially could occur under broadacre conditions had a good chance of being observed, identified and solved. In addition there was a large degree of ownership by the growers and related grower groups and many field day events were held at the sites. This ‘local ownership’ and reality of the large scale sites encouraged the use of lime to address soil acidity. The sites also presented an excellent backdrop for all aspects of the project to be presented. A summary of results from approx. 29 demonstration sites, most covering several years from 1996 to 2001 has been published (Penny & Gazey, 2002).
Experimental Achievements (selected results from 2002)

The Agricultural Production Systems sIMulator Model (APSIM) demonstrated that losses to acidity (particularly in deep layers) could be up to 60% and the yield penalty was greater in high rather than the low rainfall zone; growing Al tolerant wheat could partially offset the penalties of acidity; improved yield by growing Al tolerant wheat and ameliorating acidity was correlated with increased rooting depth and was associated with decreased N leaching. These findings were supported by experimental results from trials at Merredin and Wongan Hills (see journal publications by Tang et al. Attachment 10).

Large scale lime experimental sites proved very effective participatory research activities by providing 'real' data on the effects of grower relevant lime additions to manage soil acidity. It was demonstrated that the rates of 1-2t/ha were insufficient given the current frequency to treat subsurface acidity and that liming could in some circumstances reduce the availability of manganese (Mn) and zinc (Zn). The need to increase both soil and plant tissue testing in general was highlighted. Plant growth and yield responses at large scale experimental sites have been published in Western Australia Soil Acidity Demonstration Site Results 1996-2001, Miscellaneous Publication 24/2002, Penny and Gazey, 2002.

Leaching experiments and lime quality work determined that particle size was the main driver of lime effectiveness under WA conditions. Downward movement of lime increased as the lime rate increased and particle size decreased. Further work on lime leaching and lime quality is published in papers by Whitten et al. and in the PhD thesis Amelioration and prevention of agriculturally generated subsurface acidity in sandy soils in WA (Whitten, MW. 2003 UWA).

A large selection of current and breeding lines of wheat was tested in a soil-based screening method developed by Tang et al. The screening showed substantial genotypic variation in acidity tolerance with relative root length (pH 3.9/pH 4.8) ranging from 13% to 92 %. Many breeding lines have better tolerance than current varieties. Barley and durum wheat were found to be extremely sensitive to acidity.

Wheat grain yields were determined after lucerne (perennial), subterranean clover and serradella-based (annual) pastures or lupin crops at two sites in the Gabby Quoi Quoi catchment as part of the project for sustainable management of soil water and nutrients in the high and medium rainfall zone of WA. The project also determined the capacity for lucerne-based pastures in rotations to substantially reduce the potential for drainage of soil water below the rooting zone typically associated with annual species by increasing the capacity of the soils to hold water before drainage occurs.

Other research

The following are areas of R&D which have been highlighted during this project and are worthy of future investigation.

- The evaluation of plant-based solutions to manage deep drainage and nutrient movement in the context of landscape hydrology in conjunction with grower groups, to assess the impact of changes in farming systems at scales that enable assessment of the hydrological impact of new perennial based farming systems, as well as the profitability of all components of the farming system.
- Catchment surveys of the effectiveness of soil acidity management which compare the amount of liming materials used over a period of time with the measured and predicted levels of acidification based on production statistics and soil measurement. Such a study could be used to verify the approach at a single catchment level and be used to assess the potential to expand a monitoring regime to the WA wheatbelt and potentially could also be used to add further information on the effectiveness of different quality and particle size limes over the longer term. The benefits would be quantification of the improved environmental management and demonstrated responsibility of grain production in the WA wheatbelt.
- Further investigations into the rapid amelioration of subsurface acidity to overcome the time delay in treating subsurface acidity by surface application of lime (now the subject of GRDC project DAW00014).
- On-going breeding for tolerance to be used in conjunction with amelioration and management practices.
- Use of the APSIM model to examine the seasonal variation in wheat response to topsoil and subsoil liming in relation to the impacts of growing Altolerant crops, nutrient supply, nitrate leaching and the occurrence of terminal drought.

Intellectual property summary
The information generated by this project has been fully extended and is freely available, and no commercialisation is warranted.

**Additional information**

**Attachments**

2. Western Australia Soil Acidity Research and Development Update 1997.
4. Western Australia Soil Acidity Research and Development Update 1999.
5. Western Australia Soil Acidity Research and Development Update 2000.
7. Western Australia Soil Acidity Research and Development Update 2002.
10. Publication and Extension list.