

GRDC Soil Biology Workshop

12 & 13 December 2006, University House, Australian National University, Canberra

WORKSHOP REPORT

INTRODUCTION

The GRDC Farm Practices and New Products Lines of Business have been actively engaged in research and business development in the general area of soil biology since 2001.

With most GRDC supported projects completed or nearing completion, GRDC wishes to review achievements to date and begin a strategic planning process to identify possible opportunities for future research investment in soil biology. The review and planning processes will be considered within the broader context of the general area of soil health in Australia.

This workshop, held on 12 & 13 December 2006, is an important part of the review and strategic planning processes. The approach taken was to bring together a selection of conventional and alternate farmers with leading researchers and rural funding organisations to share experiences, results, and views. The final session captured the whole as a conceptual framework that was used to develop a list of priorities for future R&D investment in soil biology.

See Appendix 1 for a list of participants and contact details.

Copies of power point presentations will be circulated to participants in pdf format on CD.

OPENING THE WORKSHOP

Opening remarks

Peter Reading, GRDC Managing Director

Peter Reading stressed the importance of using a whole-of-industry approach to identify and address issues facing agriculture in terms of productivity and sustainability. He cited this workshop as a good example of the process in action. The workshop brought together GRDC, AWI, MLA, LWA, RIRDC and farmers and researchers from around Australia.

Collaboration across all sectors of agriculture will bring new products and practices through to market, eg phosphate solubilising microbial inoculants that are both productive and environmentally friendly. New products and practices coming through to farmers are real evidence of where we are together as an industry. We are addressing and identifying long term needs and putting programs in place to address them.

Peter Reading introduced Susan Ley to officially open the workshop.

Opening address

Susan Ley MP, Parliamentary Secretary for Agriculture, Fisheries and Forestry and Member for Farrer

Soils are the foundation on which everything in agriculture sits, so understanding our diverse and often challenging soils is central to the ongoing development of our farming industries.

Because of the diversity of soil types and the agriculture they support the R&D resources available from industry and government run the risk of being spread very thinly unless everyone involved works to a coordinated strategy that ensure research priorities are targeted effectively.

This was the central thread of my address to the GRDC's soils workshop in Canberra in December where one of the less understood aspects of soil health -- soil biology – was being rigorously assessed by researchers, farmers, and industry representatives.

The workshop's objective was to bring together a wide range of experiences to review achievements in the science so far and begin a strategic planning process to identify future opportunities. As everyone knows, soil quality is a key determinant of farm business productivity and profitability, as well as sustainability.

Also, from a wider community perspective, improvements to the health of our agricultural soils could also provide some useful insights into looking after our broader natural environment.

The increasing sustainability of our agricultural industries, especially our grains industries which despite some very difficult seasons climatically, are revealing a remarkable resilience in areas where soil management has advanced to the point where more and more farmers are able to achieve more with less, in terms of rainfall.

The ongoing development of more sustainable cropping systems that enable soils to hold onto more of what has been, in recent years, a diminishing rainfall, is testimony to the efforts of rural research and development corporations working together, and with other research providers, on this important area of research.

Everyone has a in ensuring this important, and often hidden, area of research – soil health -- gets the attention it deserves for the benefit of our producers and for our precious environment.

I urge everyone, researchers and farmers, to dig deep for the right questions so the answers that are found are able to keep making a significant difference.

The workshop was a fine example of researchers and agricultural industry representatives from around the country working together to achieve the best results in rural research and development.

Better soil health depends on R&D teamwork.

Edited extract from GRDC Ground Cover newspaper Issue 66 - December/January edition

OBJECTIVES

Martin Blumenthal, GRDC Manager for Agronomy, Soils and Environment

Martin set the context and provided further detail to clarify GRDC expectations from the workshop.

The nature of soil biology in farming systems presents us with a potentially limitless number of research questions. Therefore, the theme for the workshop is to identify key research questions to enable GRDC to focus its research investments to bring about whole system change rather than step change.

Our challenge: "Knowledgeable farmers and scientists are experiencing the new biology of the soil but few are making the connections necessary to solve the concerns and challenges. We are at the vanguard and thus bear the brunt of responsibility to find solutions." (Cliff Ramsier, Technical Director, Ag Spectrum Company, speaking at Ohio State University, 27 July 2006)

The specific objectives for the workshop were to:

- Develop clear research priorities for soil biology in farming systems
- Involve farmers and researchers in the strategic planning process
- Seek advice, identify gaps in planning, and define critical drivers required to deliver maximum benefits to farming enterprises

- Update Rural R&D Corporations and researchers on current activities in soil biology research

FARMER PERSPECTIVES

Introduction

The drought may provide us with some useful messages about soil biology and soil health. For example, in the middle of a drought, some farmers are still harvesting crops and grazing livestock while their immediate neighbours have run out of production, so:

- What is their secret?
- How can researchers work with this? (Case studies, mentors, collaboration, etc)
- How can we use this to generate new knowledge to the benefit of farmers in general?

Three farmers who are surviving well in the drought using different approaches to farming were generous enough to share their thoughts and experiences at the workshop.

Pasture Cropping

Colin Seis, Gulgong, NSW

Colin Seis has developed and implemented a pasture cropping system on 800 hectares near Gulgong in NSW. About 200 hectares is crop with cereal rye and oats, sometimes wheat. The farm runs about 4000 sheep. A Merino stud and kelpie stud are also included.

Pasture cropping requires zero till sowing of crops into perennial pastures. The pastures can be native or introduced, although better results have been achieved with native grasses. The pastures are never killed, so careful use of herbicides is required to control weeds, if needed. Weeds are also controlled by creating large quantities of thick litter through using good grazing management of livestock. There are now over 1500 pasture croppers in Australia. The practice is also used in the USA and Scandinavia. Some research into pasture cropping has occurred with Sarah Bruce at CSIRO and through the Grain & Graze program with Warwick Badgery.

The advantages of pasture cropping include increased soil organic matter, increase in numbers and diversity of perennial plants, more efficient use of rainfall and nutrients (reduced need for fertilizers), reduced crop diseases, and more profit with less risk.

The disadvantages of pasture cropping include lower average crop yields, insect problems when first starting, the need to change machinery, the need for herbicides, going against conventional thinking, and resistance to change.

More and more landholders are adopting pasture cropping and using a limited amount of chemicals. Further research into pasture cropping should include perennial grass recruitment (C4 grasses?), herbicide usage on perennial plants, building soil organic carbon, managing pests and diseases, and fertilizer management.

The practice of pasture cropping has spread to most states. If you can grow wheat you can pasture crop. There are really no restrictions other than the perennial pasture species used. This is an area requiring further research.

We are the leaders we have been waiting for

Tom Nicholas, "Solferino", Carrols Creek, North Queensland.

Tom Nicholas presented his views on problems facing farmers and how to bring about solutions through change management. Two basic problems were identified: (1) Reserves of soil nutrients, based on soil carbon, have been run down through poor management practices; and (2) There has been a corresponding decline in soil structure, water holding capacity, and mineral holding capacity

leading to compaction, reduced biodiversity, erosion, chemical imbalances, and declining populations of soil biota.

Necessity is the mother of invention. Current circumstances have put farmers under pressure to find solutions. The solution is to rebuild reserves of soil carbon. Carbon feeds biota that feed plants that feed the soil. Carbon is measurable and can be maintained at optimum levels, otherwise farming is not sustainable. The best way to bring about the changes needed is for farmers to lead the way. A critical mass of farmers changing their practices will bring about the changes needed in government and industry to support and accelerate practice change. When talking soils we should use the words “rejuvenate” or “regenerate” rather than “sustainable”. We do not want to sustain our poor soils, we want to nurture and rebuild them.

From an economic perspective, farming the soil to build the natural capital base is the core change required in thinking. From this will come more profitable and sustainable farms, improved public (urban) perceptions, and more political support for the rural sector.

Visions and Practice for a Renewable Future

David Marsh, Boorowa, NSW

Over the past eight years David Marsh has moved from a conventional mixed farming enterprise to a low cost, low risk, more sustainable system called planned grazing, as opposed to set stocking or cell grazing. The predominant form of livestock is sheep with cattle on agistment as capacity allows. He made this change after deciding that his conventional system was not sustainable and high risk.

The aim of the business is to manage sunlight, plants and time to produce profits from plants and animals, time for recreation, and habitat for flora and fauna. Energy and input costs are reduced to a minimum, plants are encouraged to proliferate to maintain ground cover and increase species diversity and animal numbers are carefully adjusted to remain within carrying capacity. Stock are regularly moved through a system of small paddocks to prevent overgrazing. Perennial pasture grasses are favoured with nitrogen supplied by legume species.

Management practices are focused on building soil organic matter and carbon levels as natural capital and as the basis for water use efficiency, productivity and resilience or sustainability. This system has enabled David to continue feeding stock and producing profits through a long period of drought. The key has been continued access to water for stock. The system is far more resilient than conventional systems and buffers production against climate variability. The system may last longer and reduce income risk, however it will not remain viable forever without rain.

This farming system has shown that triple bottom line benefits are possible through innovation and carefully managed change, despite difficult climatic circumstances.

RESEARCH EFFORTS IN SOIL BIOLOGY

GRDC investment in soil biology research

Greg Bender, consultant and facilitator, Canberra

Research into soil biology has been pursued with enthusiasm by individual researchers and research organisations for many decades in Australia. From a farming perspective, the commercialisation and adoption of *Rhizobium* bacteria as nitrogen inputs (legume inoculants) for legume crops and pastures has been a spectacular success. However, general research into soil biology for the benefit of agriculture has been characterised by scattered projects, limited research capacity, and little focus on coordination or strategic planning at a national level.

From the perspective of Rural R&D Corporations, coordinated national investment in soil biology research began with the GRDC Soil Biology Initiative in July 2001 with projects running to completion in 2006 and 2007. Key findings from the Initiative include:

- Plants are the driver for soil biology through the capture of carbon from photosynthesis
- The management of organic matter and carbon is a central theme for soil biology and also soil health
- Soil biota are reactive to prevailing conditions and often have short response times
- Farm practices have a large influence and can be used to actively change or manage soil biota
- Optimal management practices for soil biota vary across regions. There are some common themes but also major differences
- National field trials using soil fumigation clearly demonstrate that soil biota can deliver both benefits and/or constraints to plant production
- Plants can actively influence the populations of soil biota in the rhizosphere. Specificity is seen down to the level of different plant varieties within the same species
- The functions of populations of soil biota are just as important for farming as detailed taxonomic studies

In addition to research into soil biology and farm practices, GRDC has established a joint venture with Canadian company Philom Bios Ltd to commercialise GRDC research into new inoculants for Australia. The joint venture company, Philom Bios Australia Pty Ltd, is located in Adelaide and managed by Sanford (Sandy) Gleddie.

MLA Pasture Soil Biology Alliance

Bob Hannam, coordinator, Adelaide

Following on from the GRDC initiative, MLA formed a Pasture Soil Biology Alliance with AWI and GRDC. Projects commenced in July 2003 and will be complete in July 2007. The Alliance began with a knowledge and opportunity audit completed by CSIRO researchers Maarten Ryder and Gupta Vadakattu. A search for evidence of biological constraints in pastures was completed before an investment strategy was developed for research projects. The SARDI root disease testing service is developing additional DNA assays for pathogens and beneficials as well as DNA tests for plant roots. A pilot training resource manual on pasture soil-borne diseases and soil biological functions has been developed for researchers and advisors. In addition to more applied research, the program includes discovery research on the rhizosphere and chemical signalling between plants and bacteria. An external review of the Alliance was done in November 2006 with planning underway for a possible second round of investment for 2007-10.

LWA Healthy Soils for Sustainable Farms

Catherine Viljoen, LWA, Canberra

The program is funded by the Department of Agriculture, Fisheries and Forestry (DAFF) through the National Heritage Trust (\$5.2 million) in partnership with GRDC (\$1.2 million) from July 2004 to June 2008. The objectives of the program are to:

- Drive the adoption by farmers of scientifically proven and cost effective strategies for improving soil health across Australia
- Promote best soil management practices to farmers and advisors
- Relate soil health and profit
- Link soil health and practices to catchment health

There are four major regional projects and six projects focused on specific deliverables. In addition, there is a Knowledge Bank project to establish an agreed body of knowledge on soil health, set up pathways for farmer and adviser involvement, and increase the adoption of practices that sustain healthy soils. The Healthy Soils for Sustainable Farms program has widespread support within the soils community and looks forward to continued support post June 2008.

DISCUSSION SESSION

Question: How many farmers are starting to think like you? Are you in the minority? How do we convince / motivate the other 95% in thinking the way you are thinking?

Answer: This is not the sort of system that you simply apply ready-made, it is an ongoing process of making decisions that balances environmental, social and economic priorities with a whole-of-landscape vision or goal in mind. With farming systems being quite complex, it is hard work keeping up with new information, so farmers often abdicate the thinking process to someone else who they pay. Now the direction that takes you may not be where you want to go. So being in control of where you want to go and having the tools to help you make decisions in a more balanced way is very important. Changing people is hard and they need a good reason to change.

Question: What about weed management in your systems?

Answer: Grazing management rather than herbicides can give a pretty good result. In our own case, we used to have a lot of thistles. We have not sprayed for seven years now but we used to spray them all the time. If you can manage your groundcover you can control a lot of them, but you will not get rid of them. Constant groundcover will control annual weeds. However perennial weeds are more of a problem.

Question: We have been talking about low input, low risk systems, and they can be low in yield and that can fit some peoples economic model. I wonder whether you are thinking legitimately that the world can survive on low output systems?

Answer: Why do we think that because we have low inputs we have got to have low yields, we can have low input, high production agriculture. The question itself is an indication that we are not thinking very straight. We can have low input and high production but we need to get our soil right first.

Question: The soil is not an inbuilt source of all outputs. If you haven't got your inputs in balance you will run yourself down. You can build carbon in the soil but what about other minerals?

Answer: This is not necessarily the case. I do think once we get everything in balance we can get nutrients functioning and everything working. The closer that we get to how nature designed it in the first place, the easier it becomes and the more profitable it is. And that is the philosophy I use. Nature had it right in the first place, why not mimic nature more closely?

Question: Nature as a whole will recycle, man-made systems usually do not. You mention native grasses and cereals, are there any legumes involved?

Answer: Generally the sub-clover levels run at 10-15%, but there is no doubt that we are getting released nitrogen through biology. We are also getting a release of phosphorous. When we first stopped super application after 30 years, the sub-clover just about died. Now the sub-clover gets better and better all the time. It has got to be getting phosphorous from somewhere.

Question: It is very likely that you have quite high levels of free living nitrogen fixation going on. You have a very carbon input right through the year, and whenever there is moisture and the temperature is reasonable you will get substantial levels of nitrogen fixation going. However, I wonder about the phosphorous levels and probably you are using up substantial reserves from fertiliser applications over the years. What will happen 50 to 100 years down the track?

Answer: Some of us are still putting fertilizer under our crops. This is reducing all the time, as I think we are getting release of nutrients – I'm assuming. This is a fundamental point for any model that we develop in the future. We need a budget for all nutrients.

Question: I am intrigued as to where the extra carbon is located in the profile.

Answer: Carbon levels doubled well down into the profile – at least to below 200mm. This is probably because of increased root mass and deeper root penetration into the soil.

Question: Despite wide adoption of stubble retention, zero till and conservation farming, why is it that your system gives an increase in carbon but systems producing 10 tonnes of grain per hectare/ha are not increasing their carbon levels?

Answer: If you have a living perennial system that is there all the time and you sow your crop into it, rather than into bare ground, you will increase your total soil carbon levels. Baling or burning stubble also works against carbon increase. New innovations in design of machinery are needed to work in stubble and there is the issue of disease carry-over still to be addressed.

Comment: Every grower out there is interested in his soil health, and that interest is only increasing of late. However, a leap of faith is required to make radical changes in farm management. For some farmers faith is enough, but for many farmers, solid independent documented data is required to convince them that the risk is worth taking. Farmers often change their systems and some mistakes during a change-over can be tolerated, however big mistakes can cost too much. Through currently recognized main stream practice, soils are now so much better than they were before and they are improving all the time. Through minimum tillage and increased stubble retention stock can be increased and maintained in dry conditions to make a very profitable system. A profitable system can afford bagged nitrogen, lime, etc. Therefore the system can support increased production. However, farmers want to know how to continually improve their soils. If there are farmers who say you need a mind-set change to do it then we need to explore that change to see what it is and to be able to explain it to other growers.

Comment: Farmers manage change all the time. If they can actually measure a gain in output or in soil health, they will rapidly adopt the required changes. The soils in southern NSW are getting better every year, even in a drought year they are better than they have ever been. The use of lime and gypsum are making a huge difference. The efficiency of conversion of rainfall into biomass production is now phenomenal. Even stocking rates have remained pretty consistent throughout the drought. There is already significant ongoing change in soil management. An important barrier to adoption is the terminology used in soil biology. Consequently, farmers still know very little about it, much less how to use and apply any related new technologies. Farmers need specific advice and tools to measure improvements.

Comment: Some farmers are already managing soil biology on their farms with proven results. So other farmers educating farmers is probably the best way to achieve adoption. However, we do need the research to back it up because many farmers want independent data and interpretation and to see the changed practices in operation. Collaboration between farmers and research teams across Australia is essential.

SOIL ORGANIC MATTER & CARBON

The significance of organic matter fractions and how they can be measured and managed
Jeff Baldock, CSIRO, Adelaide

Soil organic matter influences and interacts with soil physics, chemistry and biology. Physical functions include improved structural stability and water holding capacity. In soils with low clay content, organic matter improves cation exchange capacity and acts as a buffer for pH. It provides energy for biological processes, a reservoir of nutrients, and contributes to the resilience of plant production systems. Soil organic matter can be divided into: (1) surface plant residues; (2) buried plant residues (>2mm); (3) buried plant residues (<2mm) including; (4) particulate organic matter (>53µm); (5) particulate organic matter (<53µm); and (6) charcoal. These different soil organic fractions contribute differently to various soil properties. Linking quantitative expressions of the

functions of soil organic fractions to their cycling is required. Research priorities for future work listed in this presentation have been captured under *Identification of future research priorities* in a later section.

Does organic matter “matter”?

Frances Hoyle, DAFWA, Perth

Organic matter input is influenced by management and the quantity and quality of residues. The rate at which it decomposes is influenced by temperature, moisture level, soil type, and management. Factors influencing the potential benefits include residue quality, climate, and the rate and timing of organic matter capture. The labile or “active” fraction responds to management and is not a constant percentage of the total pool of organic matter. It does provide a useful indicator of organic matter status and trends. There is a relationship between labile organic matter, the C:N ratio and soil N supply. Below a C:N ratio of 22, N in excess of microbial demand is released. The labile fraction demonstrates a positive relationship with grain yield. In WA, labile C is particularly important in sandy soils for N retention and availability. Up to 80% of crop N requirements can be supplied from organic soil pools. There is a natural equilibrium for the retention and loss of organic matter, with many systems demonstrating significant seasonal variability. Roots are a major source of organic matter. Plant composition and distribution control the distribution of organic matter, ie horizontal depth and distribution of roots.

REGIONAL NEWS ON SOIL BIOLOGY

Key issues for soil biology research in the northern grains region

Mike Bell, QDPI&F, Kingaroy, Queensland

The northern region is defined by Emerald to the north, Walgett to the west, Toowoomba to the east, and Dubbo to the south. Cereal grains occupy 80-90% of the cropped area with summer sorghum beginning to dominate. Continuous cropping is dominant with few ley pastures and long fallows to store soil moisture. Skip row planting and ultra wide rows are also gaining acceptance. Soil organic matter continues to fall despite direct drill and stubble retention. There is increasing reliance on N and P fertilisers. The overall microbial activity is low with the soil community often dominated by grass-specific pathogens. Microbial activity strongly stratified, vertically and horizontally, and often dominated by fungi. The presentation made a clear case for potential improvements in productivity and sustainability, eg better root systems. There is an urgent need for an effective non-grass, preferable legume, rotation. However, the potential contribution of soil biology in the northern region will require hard data and demonstrated benefits on-farm in order to precipitate changes in farming practices and systems.

Soil biology research news for southern NSW / NE Victoria

John Kirkegaard, CSIRO, Canberra

The region is dominated by acidic loams deficient in available phosphorous and with 1-2% organic carbon. Of the major soil types, kandosols/chromosols have a dense structured subsoil and vertosols/sodosols have a dense unstructured subsoil that is often sodic or saline. There has been wide adoption of new practices and technologies in the region including pasture management, break crops, reduced tillage, stubble retention, precision farming and controlled traffic. The net result of these changes has been positive although the downside is restricted root development and new root disease problems. New wheat varieties are under development to help overcome these problems. Stubble management is a dominant issue, as is management of herbicides and pesticides, pastures and ruminants. There is strong interest in soil biology but the value proposition has yet to be developed along with the tools, related management practices, and language. The appropriate soil biology for this region is not clear at this stage.

South Australia and W Victoria

Gupta Vadakattu, CSIRO, Adelaide

There is a trend towards the intensification of cereals, no-till, stubble retention, and 30cm row spacing, and within paddock management of soil spatial variability (EM mapping) for optimal matching of plant available water to nutrient requirements. The root diseases rhizoctonia, fusarium, and pythium are important restraints. With continuous wheat there is a 10-20% reduction in second and subsequent wheat crops due to deleterious bacteria in the rhizosphere. The effect is cultivar specific associated with a strong differentiation in rhizosphere communities. There is improved management of nutrient inputs through understanding of microbial functions in intensive stubble retention systems. For nitrogen there is improved synchronisation of net mineralisation, improved interpretation of deep nitrogen measurements, and a role for non-symbiotic nitrogen fixation. Increases in microbial phosphorous have improved the efficiency of utilisation by crops.

Soil biology related research for Western Australia

Dan Murphy, UWA, Perth

Higher yield trends in WA occur where farmers address a combination of soil constraints including chemical (nutrients, acidity), physical (water storage and infiltration), and biological (diseases, weeds, nematodes) factors. The best performing farms consistently increase nitrogen fertiliser application and crop diversity in rotations (pulses, oilseeds, sorghum). The latter are significant where nitrogen fixation and disease control are important. Conservation tillage improves yields through better moisture retention, reduced erosion, and better soil properties (higher carbon). A cyclical, seasonally based, change in soil properties, resources, and microbial function is particularly prominent in WA. Greater stability (resilience) is seen in the stubble retained (not burnt) systems. There is considerable diversity and depth in soil biology and soil health related research in WA. Promising work includes the development of actinomycete endophytes to control root diseases, a new analytical tool (NanoSIMS) for integrating the physical, chemical, and biological interface in soils, *in situ* measurement of greenhouse gas emissions in cropping and up-scaling of field-based data to regional scale, benchmarking soil quality across key regions in WA and a soil quality indicator package (www.soilquality.org.au), the application of near and mid-infrared technology to predict numerous soil parameters from a single scan for spatial mapping, and the development of in-field and real-time IR detectors.

INTERACTIONS BETWEEN PLANTS & SOIL BIOTA

Plants as the driver for management of soil biology

Alan Richardson, CSIRO, Canberra

Through the production of carbon based compounds, driven by sunlight and photosynthesis, plants provide a wide range of carbon based compounds that influence soil biology, chemistry and physics. These include crop residues on the surface and root mass, residues, and exudates below the surface. No-till wheat in southern NSW/NE Victoria is inhibited by soil hardness and soil organisms. Natural selection and enhancement by recurrent selection has produced new varieties to overcome these restraints to growth and yield. These varieties have differences in the profile of compounds released in root exudates. Some soil microbes also have the ability to increase the production of root exudates. The significance of these interactions is not understood. The release of hydrogen gas is a bi-product of nitrogen fixation by some strains of rhizobia. The hydrogen is consumed by soil microbes and can stimulate plant growth, eg 5-19% yield increase in canola. Two groups of bacteria have been identified that may be the causative agents. There is evidence that soil bacteria can mineralise organic phosphorous in the rhizosphere and it may be possible through genetic manipulation, to confer this ability to crop plants.

Spatial management of plant-microbe interactions for the benefit of plant health

Gupta Vadamattu, CSIRO, Adelaide

The composition of beneficial microbial communities is strongly influenced by crop type and variety. The ability to separate the plants of the current crop from the residues of the previous wheat crop could have significant yield benefits! Can we find management options to harness the beneficial functions and reduce the influence of deleterious organisms? Work presented here suggests that it may be possible to realize these benefits at minimal cost and risk for farmers. To test the potential of this research, the following questions were posed: What is the spatial distribution of microbial communities, beneficial and deleterious within and in between rows of broad acre crops? Does crop/variety type have an influence on the spatial distribution? How long does the microbial footprint from previous crops remain effective within and in between previous year's crop rows? Management options to help minimise the negative impacts of pathogens while promoting beneficial functions of biota through spatial management of seed and input placement? What is the opportunity to improve availability of applied N fertiliser through reduced tie-up associated with cereal residue decomposition?

The importance of soil biology in marginal country

Zed Rengel, UWA, Perth

Crop nutrition is frequently inadequate due to expansion of cropping into marginal lands, increased demands on soil nutrient reserves caused by elevated crop yields, and environmental and economic concerns about applying fertilisers. Nutrient-efficient genotypes are adapted to environments with low nutrient availability. Nutrient efficiency can be enhanced by targeted breeding through pyramiding efficiency mechanisms in a desirable genotype as well as by gene transfer and manipulation. Rhizosphere microorganisms influence nutrient availability and may enhance nutrient-uptake capacity, especially in nutrient-efficient genotypes. Adding beneficial microorganisms may result in enhanced availability of nutrients to crops. Understanding the role of plant-microbe-soil interactions in governing nutrient availability in the rhizosphere will enhance economic and environmental sustainability of crop production. Recommendations for future research include: (1) Incorporation of nutrients released from organic matter (amounts and dynamics) into decision-support systems for fertiliser recommendations; (2) Characterise the role and dynamics of rhizosphere microbial communities in crop rotations; (3) Determine the impacts of the expected increased use of glyphosate (in case of GM crops) on rhizosphere microbial communities, micronutrient uptake and soil-borne diseases.

Mixing, matching and measuring rhizospheres

Kathy Ophel-Keller, SARDI, Adelaide

Evidence was presented that plants have a strong influence on the composition of soil biota in the rhizosphere. Even when grown in the same soil the composition of the rhizosphere varies considerably between not only different species but different varieties within a species. This leads to the proposition that plants most probably release compounds that select, from within the available population, soil biota that are most beneficial to their growth and survival. For example, evidence was presented that wheat cultivars and different legume species select disease suppressive microflora within their rhizospheres. This observation can be applied to the selection of crop and pasture cultivars that make best use of populations of soil biota available in soils within target agricultural regions. For example, the selection of medic cultivars that have the ability to form effective nitrogen fixing symbioses with a wide range of *Rhizobium* strains already present in the soil, rather than have to rely on commercial inoculant strains. New medic lines with this ability are close to release and work has started on the selection of sub clover cultivars with the same outcomes in mind. The resources of the Root Disease Testing Service are being extended to the characterisation of root growth and communities. This requires the development of new molecular tools for the testing of root DNA and DNA from beneficial, as well as pathogenic microbes within soil and root samples.

DIRECT BENEFITS FROM SOIL BIOTA

Application of fungal endophytes to cereals

John Caradus, Grasslanz Ltd, New Zealand

Ryegrass has a naturally occurring fungal symbiont that remains within the plant and is passed on to the next generation through seed. The endophyte protects the plant from insect pests, confers drought tolerance, and increases growth, persistence, and seed production. However, it also protects the plant from grazing through the production of Lolitrem B causing staggers in livestock and Ergovaline causing heat stress, lower live weight gain, and reduced milk production. By selecting an endophyte (AR1) that does not produce Lolitrem B and Ergovaline and introducing it into ryegrass varieties, it has been possible to confer huge benefits to livestock producers in New Zealand. The adoption rate is currently 100,000 hectares per year. Grasslanz Ltd are testing the potential application of this technology to cereals. Fungal endophytes have been observed in wild relatives of wheat and barley. Therefore, an opportunity exists to develop appropriate endophytes to enhance the robustness of cereals in the face of biotic and environmental stresses.

Endophytes and ecological succession

Chris Franco, Flinders University, Adelaide

Actinomycete endophytes produce antibiotic compounds *in planta*. They prime the plant defence pathways inducing systemic resistance. They are particularly effective growth promoters of cereals producing up to 30% increases in shoot weight or root growth in six weeks. In the field, treatment increases plant emergence by 7 -16%. They have a wide host range including cereals, grasses, legumes and other dicots. Spores are readily manufactured and can be transported and stored for lengthy periods. They are currently applied as seed dressings and not effected by most pickles. Unlike chemical fungicides, they produce grain yield increases of 10-15% in the absence of disease pressure. Further research is needed to fully characterise selected strains under field conditions. For example, what is the influence of soil type, plant variety, other soil biota, environmental variables and common management practices on the performance of the inoculants? Potential inoculant strains produced from this work are being developed and commercialised by Philom Bios Australia Pty Ltd.

Contribution of symbiotic nitrogen fixation to agriculture

Ros Deaker, Sydney University

The annual contribution from symbiotic nitrogen fixation in legumes to Australian agriculture is estimated at \$3 billion as fertiliser equivalents. Pasture legumes provide 25-100 kg N per hectare per year. The contribution from grain legumes is less clear because of various crop management practices. The synchrony of N supply and demand differs according to source (legume vs fertiliser) and water management (dryland vs irrigated). However, the use of legumes is more sustainable. Effective inoculant strains need to out-compete resident soil populations of rhizobia. Optimising nitrogen fixation by legumes requires: (1) Selection of plant host and rhizobia to suite soil conditions; (2) Legume varieties tested against naturalised soil rhizobia; (3) Maximising the numbers of rhizobia reaching the plant; and (4) Use of the most appropriate formulations and application methods for inoculants. Inoculants are available as peat powders, granules, liquids, and pre-coated pasture seed. Peat powders are well established and proven, granules and liquids are new and still under development, pre-coated pasture seed is convenient but the quality is poor and getting worse. Despite legume inoculants being on the market since the 1950's, they still have not fully realised their potential as a source of cheap nitrogen for farming systems.

Optimisation of non-symbiotic nitrogen fixation (NSNF) activity in soils and farming systems across the southern Australian cropping area

Gupta Vadakattu, CSIRO, Adelaide

The potential contribution from NSNF could be up to 35% of crop nitrogen requirements under intensive cropping systems in southern regions. At present there are no crop models or nitrogen

prediction calculations to take into account this significant nitrogen input. If NSNF is included in calculations, it is usually as an estimate. Environmental factors, management practices, soil type, and the composition of local populations of biota all impact on the quantities available and when they are available. More specific influences include the influence of stubble management on available carbon for NSNF, continuous cereals versus rotational impacts, different seasonal rainfall and temperature patterns, and the influence of chemicals (particularly nitrogen fertilizers). By building our scientific capability to more reliably predict NSNF we may be able to reduce nitrogen input costs and increase nitrogen use efficiency.

DISCUSSION SESSION

Question for Gupta Vadakattu: The data from your work is interesting and has been quite widely publicized in the press and that is good to see. I would like to recommend caution in extrapolating amounts of nitrogen incorporated into soil from free-living nitrogen fixation in your work to other regions. The amounts of nitrogen as a percentage of crop needs are quite high and this could lead to some costly decisions by farmers.

Answer: The information generated is really for the research community at this stage. However, journalists do gain access to some information as a natural part of the dissemination process. This is difficult to control. The information has been deliberately limited to Mallee Project meetings because it is a project requirement to discuss results. The amount of nitrogen fixed through free-living processes is heavily dependent upon practices and environmental variables and there are no general recommendations as yet. We have used the word potential and made no promises, however, journalists can give quite a different impression.

Report from the RIRDC phosphorous workshop

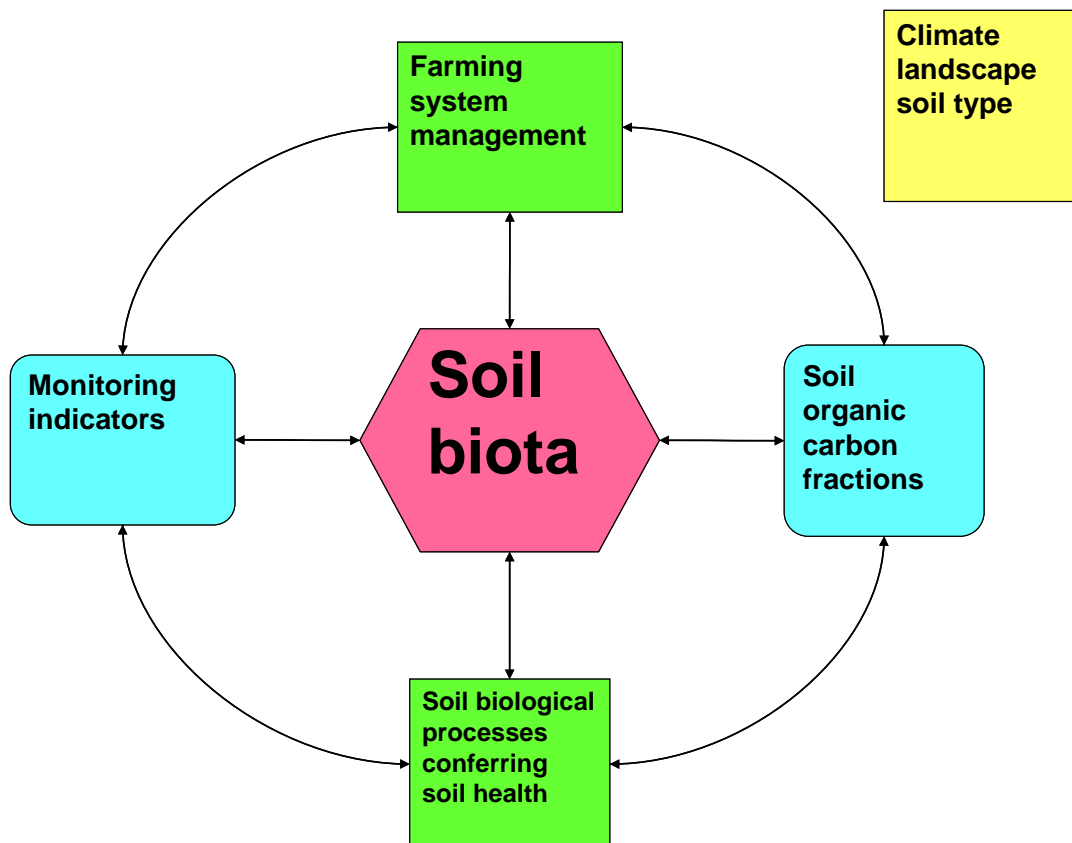
Peter Cornish, UWS

A summary of the current situation: P-fertiliser is a cornerstone of high agricultural productivity, critical soil-P thresholds are rising with yields, about 460 kilotonnes (~\$1 billion) of P is applied per annum for grain production, only about 50% of applied P is taken up by plants, the value of potentially available P in the soil is about \$15-30 billion (a national asset). How can the residual and applied P be used more effectively? This is an economic and environmental imperative. A new paradigm is required for management of phosphorous in agriculture. Recommend investment in four new project areas: (1) Quantify stocks and flows of P; (2) Unlock the soil P bank; (3) Develop sustainable fertiliser options; and (4) Use the knowledge and experience gained in decision support and extension.

FINAL SESSION: BRINGING IT ALL TOGETHER

Peter Slavich, NSW DPI, Wollongbar

Peter Slavich opened the session with a conceptual model to draw together discussions and material presented during the workshop. The model sought to clarify the role of soil biota in relation to farming system management, soil organic carbon fractions, soil biological processes conferring soil health, and monitoring indicators. All these components function and interact within the broader context of climate, landscape and soil type.



Soil biota included: Roots, rhizosphere communities, organic matter decomposers, symbiotic relationships, free-living nutrient fixers, soil structure builders and stabilisers, pathogens, and predators.

Farming system management included: Pasture resting – crash grazing; pasture cropping, rotations pasture cropping, reduced or no tillage cropping plus break crops/pasture, permanent cropping, agronomic management, and productivity as a balance between inputs and outputs.

Soil organic carbon fractions included: Labile fractions (litter and particulate matter) and non-labile fractions (humic and char-charcoal) in relation to nutrient supply, cation exchange, and carbon sequestration. The role of organic amendments (manure, wastes, black carbon) in the carbon cycle.

Monitoring indicators included: Visual assessments, field tests, laboratory tests and interpretation, and a range of specific chemical, physical and biological tests. Visual assessments are arguably the most useful for farmers.

Soil biological processes conferring soil health included: Nutrient cycling and availability, soil structure development and stabilisation, soil water storage and movement, soil aeration, and pathogen activity.

Identification of future research priorities

Rebecca Lines-Kelly, NSW DPI, Wollongbar

The purpose of this session is to develop a list of research priorities using the knowledge and experience of participants combined with material presented at the workshop. Participants were requested to put aside individual priorities and take a holistic view for the benefit of agriculture, the economy, and the environment in general. In addition, there is a need to address the concerns of federal and state governments in relation to climate change and water supplies. What is the role of soil biology and soil health here?

The model developed by Peter Slavich was used as a tool for the identification of clear priorities for investment in future research on soil biology and soil health. The following priorities were identified by participants (*not in order of priority*):

Establish networks of farmers and researchers in soil biology

- If we are to work together we need a common and agreed goal or vision. This will keep us on track. If this group can share a goal for landscapes in which we grow crops and are doing agriculture then projects will make decisions towards that goal. If we do this we should make an enormous amount of progress (David Marsh).
- Increased collaboration between farmers and researchers (Col Seis). We need to establish research and farmer linkages across the country. Tom Nicholas offered the use of 40 hectares on his property for research purposes.
- Benefit from taking a good look at some of the innovative farming systems that are out there and try to understand why they are working so well. We might be able to find new directions through this approach. Compile a list of innovative farmers across Australia as a source of potential collaborators (Margaret Roper).
- Networks in soil biology are needed urgently (Mike Bell). We have to plan for the next generation of researchers and make the appropriate linkages across different fields of research without being too narrow (Dan Murphy).

Agronomy and management

- We need to understand how to offset input costs through application of soil biology knowledge (Margaret Roper).
- Soil biology should be seen through a whole farm or holistic approach (Peter Grace).
- Temperate systems work more easily with incremental steps where we have much more of a boom and bust cycles. How do we best place our biological resources to buffer against stress (Col Seis)?
- In changing a farming system, how is that changing the composition of the soil biota and what are the implications for nutrient management (David Shannon).
- We need solutions to the loss of biological functions in cropping systems in the northern region (Mike Bell).
- A shift in focus is needed to undisturbed soils. Most research has been in cultivated or disturbed soils. More research is needed on the differences between bulk soil and biopores (John Kirkegaard, Geoff Baker & Mark Peoples).
- More work is needed on all greenhouse gas issues in relation to soils (Peter Grace)?

Indicators and measures

- Farmers need practical measures of soil biota so they know they are heading in the right direction with their systems and practices (David Marsh). Farmers need visual indicators that will help tell us we are on the right track or the wrong track (Col Seis).

- Farmers should aim for 100% groundcover all of the time. This is the best indicator of soil health (David Marsh). Are roots down far enough to capture potential benefits? Plants are the best indicators (Gupta Vadamattu).
- We need the capability to measure and predict the effects of our management practices (Jeff Baldock).
- Rather than classify farming systems and farmers into different groups we should be measuring something to choose what works most effectively on a triple bottom line basis (John Kirkegaard).
- Once we have a healthy soil how do we measure the resilience of the healthy state of a soil (Dan Murphy)? How do we actually protect the soil biota?
- Soil quality/health tests need to be standardised with agreement on interpretation (Dan Murphy). Interpretation of the same tests across different farming systems needs to be done properly (Emma Leonard & Bernard Hart).
- More work is needed on developing scientist's toys into tools for farmers (David Wolfenden).
- The development of indicators for the rhizosphere (Fran Hoyle).
- Soil quality measurements are needed rather than definitions of soil health. We need to develop tactical, remedial and other levers for farmers to apply (John Kirkegaard).
- Soil health needs to be expressed in terms of functions (Jane Aiken).

Soil organic matter and carbon

- Develop different farming systems to put carbon back into soils and maintain minimum levels of carbon. How much carbon and organic matter can soils hold? How long will different soil types take to reach the desired target, as a function of management and climate? What are the optimum levels for different soil types and farming systems? We should aspire towards carbon sequestration for reasons other than just carbon credits (Jeff Baldock, David Marsh).
- We need more work on roles of soil organic carbon fractions in terms of soil biota and how they fit into farming systems (Fran Hoyle). What is the relative value of different below ground carbon sources, eg perennial crops compared to annual crops (Alan Richardson).
- Apart from nitrogen and carbon, how do other nutrients influence the accumulation of organic matter and the roles of various carbon fractions (John Kirkegaard)? Phosphorous and probably sulphur in places is important. We need greater understanding of how fractions cycle through systems (Jeff Baldock).
- More research is needed on the interaction between soil physics, chemistry and biology. These aspects work together, not in isolation (Fran Hoyle).
- More work is needed on carbon budgeting. What is the carbon value of different sources (Fran Hoyle & Alan Richardson)?

Plant nutrition

- A means to gain access to insoluble stores of phosphorous in soils (Col Seis). What causes phosphorous to become insoluble (Bernard Hart)? Recommend investment in four new project areas: (1) Quantify stocks and flows of P; (2) Unlock the soil P bank; (3) Develop sustainable fertiliser options; and (4) Use the knowledge and experience gained in decision support and extension (Peter Cornish).
- Are there inhibiting effects of applied fertilizers to beneficial functions of soil biota? How important is this to the release of nutrients from plant materials as they break down over a season. Can threshold levels of fertiliser application be identified (David Marsh)?
- What is the relative importance of soil biology in the cycling of chemicals (Peter Cornish)?

Plant disease

- What are the factors that drive the suppression of plant diseases by soils (Mike Bell)?

Blue sky research

- In addition to core research, there needs to be provision for higher risk and speculative research. For example, new root systems from Banksias (Bernard Hart)?

Reality check: Do farmers actually want the research? What are the potential economic gains? A market analysis is needed before further investment is made in research (Steve Jones).

WORKSHOP CLOSE

Martin Blumenthal reiterated the need, clearly identified by Susan Ley, for a consistent message across industries, researchers, and funding organisations, if strong support is to be forthcoming from the Federal Government for further investment in soil biology and soil health.

Martin formally thanked all participants for their attendance and contributions.

Prepared by Greg Bender, March 2007

APPENDIX 1
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