



SOIL HEALTH ISSUES FOR AUSTRALIAN COTTON PRODUCTION GROWERS PERSPECTIVE

Survey Report by Gus Shaw



Australian Government
**Cotton Research and
Development Corporation**



© Cotton Research and Development Corporation
October 2005

ISSN 1039-3544
ISBN 1 921025 085

This work is copyright. Apart from any use permitted under the *Copyright Act, 1968*, no part may be reproduced by any process without the written permission of the Cotton Research and Development Corporation

Cotton Research and Development Corporation
2 Lloyd Street (PO Box 282)
Narrabri NSW 2390
ABN 71 054 238 316

Contacts

Executive Director: Bruce Finney
R and D Activities: Bruce Pyke
Communications: Julie Burt
Finance and Administration: Robin Logan

Telephone: 02 6792 4088
Facsimile: 02 6792 4400
Email: crdc@crdc.com.au
Website: www.crdc.com.au

Disclaimer: This publication is designed to be an information source to allow greater understanding of current levels of awareness of soil health issues and also to identify research gaps. This information has been prepared by the author with input from growers. The views and comments in this publication therefore represent the opinions of growers and not those of CRDC, the CCC CRC or the report author. CRDC, CCC CRC (or its participants) and the author accept no responsibility or liability for any loss or damage caused by reliance on information, management approaches or recommendations contained in this publication.

Acknowledgements: CRDC, Helen Dugdale, Lewis Wilson, Ian Rochester, Nikki Seymour, Dave Kelly, David McKenzie, and the many growers who participated in this survey and freely gave up their time to either assist with development of the survey questions or with the answering process.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	4
SUMMARY OF IDENTIFIED RESEARCH AND EXTENSION SUGGESTIONS	6
CHAPTER 1: UNDERSTANDING SOIL HEALTH	8
CHAPTER 2: MANAGEMENT PRACTICES	11
CHAPTER 3: COMMERCIAL PRODUCTS AND PROGRAMS	14
CHAPTER 4: VESICULAR ARBUSCULAR MYCORRHIZA (VAM)	15
CHAPTER 5: ENVIRONMENTAL ISSUES	16
CHAPTER 6: MEASURING AND MONITORING	17
CHAPTER 7: SOIL STRUCTURE	18
CHAPTER 8: CHEMICAL FERTILITY	20
CHAPTER 9: EXTENSION SERVICES	24
CHAPTER 10: FUTURE SUGGESTIONS FOR RESEARCH AND EXTENSION	26

EXECUTIVE SUMMARY

The Cotton Research and Development Corporation (CRDC) has made significant R&D investments in soil health research over recent years.

Initially the focus was on nutrition: studying nitrogen, phosphorus, potassium, iron and zinc. The research focus then moved to soil physical fertility: studying compaction and ways to manage this, including gypsum, deep ripping, rotations, minimum tillage, permanent beds and controlled traffic rows using GPS technology. More recently the research emphasis has moved to soil biology: What do soil organisms do, can they enhance fertility and what can we do to promote their presence.

This study aimed to examine current knowledge and understanding of soil health and management issues. It also aimed to identify the cotton community's "soil health" needs in order to enhance the research and extension effort in this area.

The Soil Health survey extended from Hay in the south, to Emerald in the north. Thirty farmers were interviewed during July 2005 at: Hay, Hillston, Narromine, Trangie, Warren, Breeza, Gunnedah, Narrabri, Pilliga, Moree, Mungindi, St. George, Dalby, Warra and Emerald. All interviews were face to face except for the Emerald growers and one Moree grower, who were interviewed by phone.

If we exclude growers who are currently using poultry and feedlot manure, three growers were currently involved in utilizing alternative approaches to biological soil health. Of the remaining growers, some were open minded about alternative methods but felt that without good scientific rigour to support the products currently on the market, they were reluctant to take these products on board. Other farmers in the survey expressed a degree of caution towards the subject of soil health.

'Soil Health' is seen as such a general term, it is understandable that there are a variety of definitions. It may be more useful to call it 'Soil Biology' or 'Soil Ecology', as a 'healthy' soil encompasses physical, chemical and biological properties. Hence the growers in this survey all seemed to have a varied understanding of what 'Soil Health' means to them.

However, they all agreed that it embraced a number of factors: It needed to be an active soil; to have good structure with plenty of organic matter; be well balanced nutritionally and to be rich in macro and micro organisms. It needed to be a soil that was easy to manage, grow good crops and be able to repair itself.

Growers were very comfortable discussing the physical and chemical aspects but were a little unsure about biology and admitted that they had seen very little scientific information on this topic.

Growers spoke about a range of factors which they thought were key to good soil health including rotations, organic matter, organic carbon, sodicity and nutrition.

Their opinions on the factors which can limit production included: nutrition, sodicity, soil biology, salinity, soil management, disease, Vesicular Arbuscular Mycorrhiza (VAM), residual herbicides, organic matter levels, waterlogging, water use efficiency and education.

Views of which management practices can affect soil health included: rotations, stubble management and organic matter accumulation, care of soils under wet conditions, min-till, permanent beds, controlled traffic systems using GPS technology and field architecture relating to waterlogging were felt to give the biggest benefits in the short to medium term.

Growers displayed a certain amount of cynicism towards soil health products and programs. A small number were more supportive. They discussed a range of topics relevant to commercial products and programs including commercial soil testing for soil health, the use of soil health products and their profitability.

The majority of growers have a basic understanding of VAM. Current drought conditions, forced long fallows and the fear of long fallow disorder heightened grower awareness of VAM and the consequences of low VAM numbers.

On environmental issues growers were very satisfied with the information received and practices in place by CRDC and the Cotton CRC. For example: breeding

new GM varieties, BMP program, reduced pesticide use and reduced water use. Hence, they generally felt that they didn't have any major environmental problems. However, some growers were concerned about green house gas emissions, the over use of nitrogen, residual herbicides, water issues, spray drift and sodium.

Another major aim of this survey was to find out growers' opinions on soil and nutrient testing: did they test? And if so where they confident with the results?

The majority of growers interviews use nutrient soil testing to measure and monitor soil health. Others made visual observations of the soil and crop. Some employed a more comprehensive soil health monitoring program.

All growers were comfortable with their level of knowledge about soil structure and were well aware of the problems associated with compaction. They all had soil management programs in place to minimise and manage compaction. Growers discussed a range of other factors related to the soils physical management including waterlogging and field architecture, poor quality water, key soil factor maps, EM surveys.

Growers used a range of tools to assess soil structural qualities These included soil pits, sodicity testing, yield, infiltration and internal drainage, friability, capacitance probes and root activity.

Growers opinions of the key factors influencing chemical fertility management included: soil tests, paddock history and grower experience, tissue and petiole testing and on farm nutrition trials. Growers raised a range chemical fertility issues including concerns about the accuracy of soil test results, selection of soil sampling sites in relation to crop yield mapping, soil samples being kept separate or bulked prior to laboratory analysis, the use of separate soil samples to produce maps of key soil factors and excessive use of nutrients under high yield crops.

Farmers stated that they felt that they were not receiving adequate extension information about soil health issues. They trust CRDC/ CRC and look

to CRDC for leadership and direction on this issue and have faith in the cotton industry's research and extension teams as an independent source of information, supported by good science. Growers did not, however, feel as confident about commercial information from resellers and salesmen.

Those interviewed highlighted five areas of concern in relation to the extension of soil health information: measurement of VAM and other soil biota, SOILpak, nutrition, and organic carbon. Other extension needs raised were: sodium, residual herbicides, green house gases, managing sodic sub-soils and nutrient recycling.

Growers expressed a desire to learn more a basic overview to provide a better understanding of soil biology; the affect of farming practices upon soil biology; microbial soil balance and the impact of rotation crops on microbial activity and balance; nutrient recycling and the relationship between soil biology and crop nutrition.

The majority of farmers believed that they will face soil health problems in the future. Disease, nutrition, mono-culture farming and nematodes were raised as their potential concerns. Sodicity, weeds, herbicide movement into river systems and green house gases were also mentioned as possible future challenges.

Overall, the growers surveyed were very enthusiastic about managing the health of their soils and were keen to learn more.

It is clear from the survey that 'Soil Health' involves many different issues which rely on informed management decisions as well as a range of issues, which are at the mercy of nature. The effective communication, extension and adoption of R&D outcomes is a crucial element in assisting the industry to meet and overcome these challenges.

CRDC and the Cotton CRC hope that the results of this survey will assist in the determination of targeted research and the uptake of knowledge. Key Recommendations arising from this survey can be found at the end of each chapter and are summarised on page 6 and 7.

SUMMARY OF IDENTIFIED RESEARCH AND EXTENSION SUGGESTIONS

Chapter 1: Understanding Soil Health

1. A need for better basic understanding of soil biology
2. Managing organic carbon, nitrogen and rapid breakdown of OM
3. High N rates: effects on soil biota; efficacy of uptake by plant
4. Bollgard technology and its effect on availability of other nutrients
5. Managing microbial activity in terms of breakdown of OM, nutrient recycling, disease management, and how to measure microbial activity
6. VAM: information needed on long fallow disorder, rotation crops, measuring VAM content, biological products
7. Fungi: more extension needed on 'good' and 'bad' fungi
8. Application/placement of nutrients and whether it has a negative effect on soil microbes
9. Back to back cotton – possible decline in soil fertility and biology
10. Salinity – extension of knowledge

Chapter 2: Management Practices

1. Information on management practices in general to improve soil health
2. Information on the economics of various rotation regimes
3. Information on the comparisons of various rotation crops' ability to enhance soil biota
4. Research into the interactions between soil biota and cotton plant and its subsequent effect on yield potential
5. Information comparing NH₃ and Urea and their effects on pH and soil biota
6. Research into the benefits of poultry and feedlot manure Information on possible resistance to RR, and movement off-farm of RR volunteers

Chapter 3: Commercial Products and Programs

1. Credible information from independent cotton industry organisations on the benefits of commercial biological products
2. Comparative farm trials needed
3. Standards and protocols to be set for soil and leaf testing

Chapter 4: Vesicular Arbuscular Mycorrhiza (VAM)

1. More information is needed about managing for better VAM populations
2. Better laboratory testing of VAM samples
3. Simple tool for in-field use to measure VAM levels
4. Information on water-injected inoculum
5. Knowledge on VAM problems affecting yield

Chapter 5: Environmental Issues

1. Environmental effects of methods of fertiliser application
2. Better management/knowledge of residual herbicides and possible run-off
3. Benchmarking of environmental achievements

Chapter 6: Measuring and Monitoring

1. Information on how to measure soil health, using: soil pits, EM surveys, yield maps, biological tests and soil tests
2. Credible information on benefits of biological tests

Chapter 7: Soil Structure

1. Advice on preparing and using "Soil Factor maps"

Chapter 8: Chemical Fertility

1. Information on fertiliser recommendations for higher yielding crops
2. Information/recommendations for split applications during the season
3. Information on P and K limiting production
4. Deep stratification under no-till situations
5. Improvement in petiole testing
6. Interpreting test results or 'trends'

Chapter 9: Extension Services

1. More extension on: credible and rigorous methods of measuring VAM levels
2. Benchmarking of soil biota
3. SOILpak used more effectively
4. Nutrition needs and effects of large amounts of N
5. Other nutritional elements which may be limiting growth
6. Methods and timing of applying fertiliser, including no-till, direct drilling
7. Relationship between VAM and nutrition
8. How to raise organic carbon levels and its effect on soil: structure, compaction and organic carbon levels
9. Trials on biological products
10. Effects of residual herbicides on soil organisms and diseases regional workshops on managing soil health

Chapter 10: Future Suggestions

1. Information needed on the relationship between nematodes and Fusarium, and then how to manage this problem
2. Farming systems trial comparing 3 systems: pull, rake and burn; BMP; and biological management and their effects on soil health
3. Rotation crops impact on soil biota
4. Information about the relationship between soil biota and disease
5. Research comparing the 2 systems of testing: chemical soil testing vs biological soil testing
6. Regional workshops on soil biology

CHAPTER 1: UNDERSTANDING SOIL HEALTH

Grower's understanding of soil health differed. All growers held the view that soil health included the physical, chemical, and biological properties of the soil. It embraced a number of factors. It needed to be an active soil, to have good structure with plenty of organic matter, be well balanced nutritionally and be rich in macro and micro organisms. It needed to be a soil that was easy to manage, grow good crops and be able to repair itself.

Others focused more on biological soil health, describing it as the whole ecosystem under the soil including the spread and abundance of both macro and micro organisms from earthworms and fungi down to the smallest bacteria. It was the balance of these organisms which provided a favourable environment for crop growth and enhanced crop production. One farmer likened it to an IPM system, everything in balance with lots going on under the surface and an active cycling process in place, related to what was happening above ground as well.

Another understanding of soil health was one that gives a plant no limiting factors. That is—an economical sustainable system which is environmentally soil friendly. A soil possessing good organic matter and organic carbon levels, a healthy nutrient recycling process, maintenance of VAM populations, and good disease management. A soil that will sustain high yields with minimal inputs.

Other thoughts were that organic matter levels were the key. Having a soil that breaks down the stubble, has good tilth and is friable and easy to work. Also that soil health was tied to aerobic/anaerobic activity.

Some growers admitted they did not have a good understanding of soil health, indicating that they had not addressed this aspect and that they felt it was too detailed and technical for them to understand.

Key Factors in Soil Health

Growers spoke about a range of factors which they thought were essential to soil health:

Rotations were considered important for several reasons. Leguminous nitrogen was considered far more sustainable than applied nitrogen, and that

rotation crops also provided the physical benefits of soil amelioration, and enhanced the quality of cotton farming systems. Growers believed that mono-cultured cotton country eventually resulted in un-healthy soils. Rotations also lessened disease risk, enhanced VAM populations, and reduced the chances of long fallow disorder.

Rotations ranged from four to five years (4/5:1) cotton to one of wheat through to a 100% (1:1) cotton/wheat rotation. Growers were interested in green manure crops, particularly vetch, between the harvest of the winter crop and the next cotton crop. Growers also spoke of sacrificial wheat crops and of sorghum crops in relation to long fallow disorder and VAM management.

Organic matter was high on farmers priority list. The priority of all farmers was not to burn stubble except where fields were to be lasered. Crop residues were mainly incorporated but some farmers left some on the surface to reduce the speed of organic matter breakdown. There were some concerns with stubble management and organic matter. In very dry winters it can prove a real headache for machinery.

It seems that relative to the volume of stubble that is incorporated, there is only a limited build-up of organic matter. On some irrigation country the stubble is breaking down at least as fast as it is being returned to the soil.

Organic carbon was considered in conjunction with organic matter as critical in the soil health process. Growers were aware that Australian soils were historically low in organic carbon. Organic carbon was a good indicator of soil health but very difficult to increase and maintain over time. The question was asked, 'how best to management it?' Some growers were concerned that the high inputs of nitrogen at the start were contributing to the rapid breakdown of organic carbon in the soil.

Sodicity management is a big problem on our cotton soils both in the topsoil and sub-soil. To help minimise the effects of sodicity, majority of growers have implemented a soil management program including rotations, stubble management and organic matter accumulation, care of soils under wet conditions, controlled traffic and GPS technology,

permanent beds, min-till and a gypsum application program.

Nutrition is of concern in terms of the high rates of N being applied and the impact of this on soil biota, as well as the efficiency of uptake of nutrients by the plant and Bollgard technology and the demands this might place on the uptake of other soil nutrients.

Growers are concerned whether the application of high rates of concentrated fertiliser in a concentrated band is having a negative impact on soil biota, eg, NH₃ and mycorrhiza. To alleviate this concern some growers are split-applying their N up to five times.

Concerns were also expressed about rates of nutrients being applied and the efficiency of uptake by the plant.

Are farmers over compensating in their nutrient application? Due to various soil processes a lot of these nutrients are unavailable to the plant. Growers wanted to know *"Is there a better way?"*

With the advent of Bollgard technology, 'bigger crop in a shorter space of time'. Growers also want to know *"Will this have an impact on the availability of other soil nutrients?"*

Soil chemistry/soil biology, microbial activity and pathogens

Farmers admit they know little about this subject. They believe they are very important for the breakdown of trash and the cycling of nutrients but are at a loss as to understand how to manage them. They also felt that they needed more information to understand nutrient recycling, measuring and benchmarking soil organisms, and disease management.

> **Soil biota management** was of concern. To achieve a diverse and abundant population of soil biota requires pro-active soil management. Growers must aim for an optimal soil environment to achieve a healthy balance. Are we farming in a way to enhance the soil biota environment or have we created an environment hostile to their well being in which we struggle to maintain numbers? Are other questions growers want answers to.

> **Nutrient recycling** was considered important and something to aim for. Growers felt that anything that can be done to improve the bio-mass which can be incorporated back into the soil must help with nutrient recycling. However, they expressed the opinion that too much bio-mass can also affect N uptake. When the cycling process is active, plant nutrient status is enhanced. Without appropriate microbes plants find it much harder to access these nutrients. A farming systems incorporating a regular rotation crop assists in the nutrient recycling process. The key to initiating the nutrient recycling process is moisture.

> **Disease management** was considered far easier in a healthy soil with a well balanced and abundant soil biota population where diseases like Fusarium and black root rot find it more difficult to gain a foot hold. In an un-healthy soil the predators have been taken out (a bit like an Integrated Pest Management (IPM) system), perhaps due to our mono-culture system and/or the fertiliser we use and our methods of application.

> **Other concerns** included carbon ratios, soil structure and it's management, problems with residual herbicides, the use and effect of feedlot manure, trash and liquid effluent, field architecture and waterlogging. Some believed that *"good agronomy, (get the basics right) and all else will fall into place."*

Micorhyza/VAM

VAM was on every ones mind considering their current drought situation. Some growers have had fields out of production for three to four seasons. Issues raised by growers included: long fallow disorder, rotation crops, measurement of VAM, and biological products.

> **Long fallow disorder** was of concern to all growers because of the drought. Most had country which had been bare fallowed for an extended period of time. In the past farmers had been hurt by long fallow disorder. Some were looking for an accurate VAM measurement to begin some sort of benchmarking and monitoring. Others were thinking about using a "biological product" to help alleviate the problem.

- > **Rotations** were considered a crucial part of **VAM management**, using both cash and sacrificial crops. There needed to be some thought go into crop selection as some had little if any impact on VAM numbers.

Nematodes

Most farmers were unconcerned about nematodes, knew little about them and were not high on their list of priorities. One was aware of what damage they could do, particularly as a vector for Fusarium. Another grower had sent soil samples away to a lab to see what nematodes were present in his soil. Good nematodes can be a good indicator of soil health.

Fungi

Most growers were unfamiliar with fungi or their importance. Some were aware that fungi were important in the breakdown and decomposition of trash and that fungi were a good indicator of soil health. Others equated fungi with disease.

The impact of soil microbes on the release of N, P, K, and S

Responses to this topic varied. Some had little to offer, while a few offered the following comments:

Healthy and balanced microbial activity is important in the release and availability of soil nutrients on all soils, particularly on alkaline soils that tie up these elements.

One concern was expressed in relation to the high concentration of fertiliser on soil microbes. With permanent beds and GPS technology, fertiliser is being placed in the same position every time. Is this zone causing damage to soil biota? Should the fertiliser be spread right through the hill to reduce this effect? NH₃ can be quite antagonistic in this regard.

Disease

Growers were primarily concerned with fusarium and black root rot. Factors considered important in disease management included: research and extension, selection of varieties, healthy soils and rotations (farming systems).

Soil Health Issues Limiting Productivity

Growers were mainly concerned about nutrition, sodicity, soil biology, salinity, soil management, disease, VAM, pre-emergent residual herbicide, organic matter levels, waterlogging and field architecture, water use efficiency and education.

Nutrition

Many of our cotton soils test very highly in P and K but this is not reflected in the plant tissue tests. P and K can be tied up quickly in alkaline soils. Considering the amount of money spent on the application of these elements, what can be done to improve their efficiency of uptake?

Most farmers were concerned at the amounts of fertiliser they were applying to their crops, particularly nitrogen, which impacted negatively on organic carbon levels in the soil and interfered with the natural nutrient cycling processes. This encouraged growers to apply more nitrogen resulting in a treadmill type reaction.

A lot of our synthetic fertiliser are salt based. It was felt that these fertilisers can have a negative effect on the soil micro-organisms and can also interfere with the soils natural nutrient recycling processes.

Growers also discussed the importance of leguminous rotation crops as an alternative and superior source of nitrogen, the possibility of using poultry and feedlot manure, liquid effluent, and imported trash. Concerns were raised regarding the decline in soil fertility and soil biology in back to back cotton farming systems.

Sodicity

Sodicity was of concern to most growers, certainly those south of Emerald. Apart from compaction, sodicity is associated with high pH which is in turn associated with poor nutrient uptake. One grower observed that on older, minimum tillage country the sodium problem had improved a lot, but on newly developed country it could take up to six years to get the system working, to flush some of the sodium through the system and give soil health a boost.

Soil Biology

Two growers compared and discussed their zero-till, direct drill dryland farming country which now has a large earthworm population compared to similar irrigation country which has none and asked the question *"What are we doing wrong?"*

Other soil biology factors raised included disease, particularly Fusarium and black root rot, sustainable organic matter levels, the impact of NH₃ and other synthetic fertilisers on soil biota, the impact that a mono-culture cotton farming system has on soil biology, and how high rates of nitrogen can affect soil biology particularly nutrient recycling.

Salinity

Salinity is considered by only 1 or 2 growers as their biggest threat, while another 2 growers considered it a possible threat. They asked *"What to do about it? How to manage it?"*

Vam

VAM, the drought, coupled with forced long fallows and fear of long fallow disorder was on the minds of many growers.

Waterlogging

Waterlogging was identified as a major yield limiting factor on all cotton farms. Yield mapping and modified field architecture has gone a long way towards correcting this.

Other Health Issues Limiting Productivity

Other limiting factors mentioned by growers included soil structure, seedling establishment, pre-emergent residual herbicides, water use efficiency and lack of education/knowledge on soil health issues.

CHAPTER 1: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. A need for better basic understanding of soil biology
2. Managing organic carbon, nitrogen and rapid breakdown of OM
3. High N rates: effects on soil biota; efficacy of uptake by plant
4. Bollgard technology and its effect on availability of other nutrients
5. Managing microbial activity in terms of breakdown of OM, nutrient recycling, disease management, and how to measure microbial activity.
6. VAM: information needed on long fallow disorder, rotation crops, measuring VAM content, biological products
7. Fungi: more extension needed on 'good' and 'bad' fungi
8. Application/placement of nutrients and whether it has a negative effect on soil microbes
9. Back to back cotton—possible decline in soil fertility and biology
10. Salinity—extension of knowledge

CHAPTER 2: MANAGEMENT PRACTICES

Introduction

All growers said that rotations, stubble management and organic matter accumulation, care of soils under wet conditions, minimum tillage, permanent beds, controlled traffic systems using GPS technology, were the steps to giving the biggest benefits in the short to medium term.

97% of growers were using some form of rotational cotton farming system. Rotational crops included wheat, barley, chickpeas, vetch, forage sorghum, canola, maize and green manure crops.

All growers had adopted a 100% stubble retention program. Growers in summer dominant rainfall areas said stubble could be a problem in dry winters resulting in stubble not breaking down, causing nitrogen tie-up and problems with planting machinery.

Other management practices of concern included field architecture and waterlogging, reduced use of NH₃ in preference to urea, split application of nitrogen, soil testing, seedling establishment, moisture monitoring using capacitance probes, and the reduced use of residual herbicides.

Long fallow, VAM and rotations

Almost all farmers were concerned with drought induced forced long fallows, maintenance of VAM numbers and the role rotation crops can play in healthy VAM management. That is: how to maximise VAM numbers for the cotton crop. Some spoke about a 1:1 wheat/cotton rotation. For others the rotation was four/five years cotton to one of wheat. Others referred to sacrificial crops to boost VAM numbers. One grower aims to grow vetch between the wheat harvest and the following cotton crop, sown on moisture in February and root cut and worked in prior to winter. Perceived benefits gained from this farming system are fallow moisture from winter rain, improved water use efficiency (WUE), improved soil structure, maintenance of VAM numbers and more efficient fertiliser use.

There were only a few growers not concerned about VAM because they had not encountered the problem or because they knew it happened occasionally but were just prepared to accept it.

There were some downsides to rotation crops. They were predominantly cotton/wheat rotations. Legumes tended to harbour black root rot (BRR), and rotation crops were not that profitable. One grower admitted that he had never been shown that a rotation crop/cotton farming system was more profitable than a mono-culture cotton farming system, which was his preferred option.

Stubble management

97% of irrigators incorporated all their stubble, aiming for good soil/stubble contact to assist with decomposition. A few left wheat stubble on the surface to help reduce evaporation but in a dry environment they must incorporate to allow time for decomposition. Even then they can run into trouble at planting time. A few who employ the sacrificial wheat scenario, leave the stubble standing. It breaks down when the cotton canopy grows. One grower incorporated and applied a stubble digesting brew, hoping to assist the decomposition process.

Dryland farmers prefer to leave their stubble on the surface.

Reasons for high yields

Exceptionally high yields have been achieved by growers during the past three or four years. The major reasons include the breeding programs coupled with Bollgard technology, long hot seasons and field architecture designed to reduce waterlogging to a minimum by increasing the speed of irrigation. That is—getting the water on/off as quickly as possible, using bigger heads, shorter runs, laser levelling to increase grade and remove localised waterlogged areas, re-designed tail-drain systems and increased pump capacity.

The locally based IDO's were useful in extending and assisting in the integration of research to farmers through regional trial and demonstration programs. Other factors raised included: nutrition (higher rates, split application, deep banding of fertiliser for dryland growers, and foliar), and irrigation management assisted by capacitance probes. Improved rotational cotton farming systems, improved cotton agronomy/management, and improved soil management were also mentioned.

Overhead irrigators

20% of farmers interviewed had installed overhead irrigators or had plans to do so when the water situation improved. Others were closely watching the situation. To those who have them or plan on installing them, they believe they have a huge future.

Northern growers in more summer dominant rainfall zones predict water savings of around 30%. Southern growers in winter rainfall zones were of the opinion that the water needed for overhead should reflect that for flood. For these growers the advantage should come from a predicted 20% yield increase, providing better WUE.

A number of other advantages were mentioned including improved yield with less water, better irrigation management (better use of rainfall, more timely and accurate water application, and more efficient plant establishment), reduced waterlogging, better seedling disease management by not saturating the soil, stubble management made easier, no tail water problems, integrates well with 15" cotton, lack of compaction and ease of operation.

Growers also offered a few words of caution. The country has to be level and with some slope to drain the paddock. It doesn't have to be perfect but must have some slope. In the event of big storm events the country must drain. Getting the water off is important.

"Overhead irrigators are a good concept but they are machines which are set to run within certain parameters. Get outside those parameters and there will be problems."

Compaction

All growers were well aware of the problems associated with compaction and had a soil management program in place designed to minimise and manage compaction. Management options included care of soils under wet conditions, controlled traffic systems and GPS technology, minimum tillage, permanent beds, rotations and biological ripping, stubble management and organic matter accumulation, and soil pits. Not all growers do everything listed above but all growers do most of what has been included.

The advent of GPS technology has allowed growers to free up parts of their soil management program. Some deep rip more often, others are prepared to flatten their beds to better manage their stubble, confident that with GPS technology they will place the wheel tracks in exactly the same place as before. Other growers are ripping the furrows. Roundup Ready (RR) technology has aided in reducing the number of passes through the field.

Dry harvests experienced during the past three or four years have been great in terms of improving compaction management but all growers are aware that a wet year could be just around the corner, which could set things back a bit.

Stubble management and decomposition has been a problem for growers during the drought, particularly for those in summer dominant rainfall zones in relation to sowing machinery adjustment and modification.

Yield mapping

50% of growers interviewed had yield monitors fitted to their pickers. Of these growers 60% were still gathering yield data. Some had plans in place to progress to the next step. 40% had moved on, in that they had mapped yield, overlaid elevation data and were in the process of or had completed laser levelling the country, plus had other ideas for field architecture. Two growers had progressed to variable rate fertiliser application. There appeared to be some hesitancy amongst some growers to progress beyond yield data collection.

Preferred rotations

Growers rotational preferences differed somewhat:

- > Cotton/wheat (1:1)—39% of growers opted for this cropping system. Some were prepared to replace wheat with a winter legume or sow a sacrificial green manure crop following the wheat harvest. Reasons for the one to one cotton/wheat system were that it gave plenty of time to prepare cotton seedbeds for sowing, it helped put more organic matter back into the soil and helped with Fusarium management.

One grower had concerns about future water availability and in future cotton may only be a one in three year option. He was looking at field peas, chick peas and canola to help fill the gap.

"Would the introduction of these crops into the cropping system provide greater opportunities for soil bio-diversity by providing soil organisms with a chance to grow under crops they prefer more than simply cotton and wheat?"

He was also looking at enhancing his WUE under his existing system, aiming to conserve all rainfall between the wheat harvest and the following October, enabling him to sow on rain moisture thus avoiding the pre-irrigation and delaying his first crop irrigation until the first week in December. He has achieved this objective in 2 out of the past 3 seasons, improving his WUE by 20%.

- > Cotton/Wheat 2:1—34% of growers had opted for this cropping system although some were planning to move to the 1:1 system to help manage BRR.
- > 16% were looking at a more diversified approach to cropping systems using faba beans and soybeans in the cotton rotation; cotton/chick peas/ wheat; sorghum/wheat/cotton; cotton/chick peas/corn; or cotton/wheat/corn.
- > 11% of growers used a cotton mono-culture and suggested that economically, a cotton mono-culture is more profitable than any other cropping system. One grower said that if he had more land than water he would go to a 2:1 rotation of cotton and wheat.

Does soil health influence WUE?

All farmers interviewed believed soil health was partly physical. A poorly structured soil will need more water to grow the crop, will have less capacity to benefit from rainfall events and will have lower yield potential. Other factors raised by growers included compaction, stubble management and organic matter accumulation, sodicity, aerobic/ anaerobic conditions and the absence of earthworm tunnels and old root channels.

The effect of soil organisms is not so clear. Growers don't understand where the envelope can be pushed next. Maybe the interaction between soil biota and the plant is the next limiting factor in the equation

to achieving the high yields our current varieties have the potential to achieve.

Interactions of farming practices with soil health

By far the most significant response to this question was in terms of soil compaction. All growers were well aware of compaction and the problems this had caused in the past years and had a soil management program in place to minimise and manage compaction.

There was a concern regarding Anhydrous Ammonia (NH₃) and urea. Those who use NH₃ do so because it is the most convenient form of nitrogen for their farm management system. Some growers have reservations about its use and effect in terms of pH and soil biota. There is a move toward urea for both agronomic and soil biology reasons.

Poultry and feedlot manure were also mentioned as being beneficial from a nutritional and biological sense and as an ameliorant in heavy cut country.

Herbicide management and rotation crops

Growers were fairly comfortable with herbicide management relative to their rotation crops. They had things fairly well sorted out in terms of herbicide risk and damage. The introduction of Roundup Ready (RR) technology has helped here.

Do residual herbicides have a negative impact on soil organisms?

68% of those interviewed agreed that residual herbicides had a negative impact on soil organisms, 28% said they didn't know and 4% said residual herbicides had no effect.

RoundUp Ready (RR) technology has helped reduce the reliance on residual herbicides and the effect that residuals can have on the germination and early growth and development of cotton following post-plant rainfall events.

Other concerns included RR resistance, and the control of RR regrowth and the movement of RR volunteers off-farm onto adjacent farms and into waterways and gullies.

CHAPTER 2: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. Information on management practices in general to improve soil health
2. Information on the economics of various rotation regimes
3. Information on the comparisons of various rotation crops' ability to enhance soil biota
4. Research into the interactions between soil biota and cotton plant and its subsequent effect on yield potential
5. Information comparing NH₃ and Urea and their effects on pH and soil biota
6. Research into the benefits of poultry and feedlot manure
7. Information on possible resistance to RR, and movement off-farm of RR volunteers

CHAPTER 3: COMMERCIAL PRODUCTS AND PROGRAMS

Commercial Soil Health Products and Programs

Aside from interest expressed in poultry and feedlot manure, compost and gypsum, 76% of growers were cautious of soil health products and programs.

Growers felt that information had little foundation and scientific base, was anecdotal and delivered in testimonial form. Very few if any salesmen were prepared to conduct comparative replicated trials to substantiate their product.

These growers look to CRDC and the cotton research team to lead the way and shed some light on this issue.

A small group were more supportive and accepting of these products. Although still very cautious they believed there were knowledgeable and trustworthy products and people out there. It was just a matter of sourcing the right people and products for you. They spoke about VAM products, stubble digesters, Polyacrilimides (PAM), seaweed, humic acid and humates.

Finally, a small group felt that good basic agronomy is the way to getting better returns and that there are no quick fix products out there.

One grower acknowledged that a big problem with "ramping up" a soil biological system was the time it takes once the country has been allowed to run down. This has a dampening effect on peoples enthusiasm.

Commercial soil testing for soil health

72% of growers had no experience with these soil tests and question their scientific rigour, reliability and trustworthiness, asking how these soil tests can help them.

A small group were more open minded, indicating guarded interest and support. They suggested there is a need for some method of benchmarking against which growers can measure progress and indicate what farming practices might be advantageous or disadvantageous. One grower suggested a set of agreed standards for measuring soil biology should be established before full scale testing could

commence, sighting sampling protocol and transport of samples to laboratories as two examples of possible failure before laboratory testing even commences.

Two growers have embraced soil biology issues and were progressing alternative systems on their farms, one admitting it required a quantum leap in faith and patience to follow the process through to achieve the desired outcome.

Do you use soil health products?

66% said no, 21% said on a trial basis only and 13% said yes. Of those who had trialled products some could not remember what they were. Of the remainder seaweed, humates, humic acid, stubble digesters, VAM inoculum, compost, poultry and feedlot manure and gypsum were the main ones. Those working with specialist laboratories/people were using more sophisticated custom made products.

Are you comfortable with the commercial information you are receiving on these products?

Growers committed to a soil biology program felt comfortable with those people they were working with but very cautious about others. The remainder were not comfortable with the commercial information because it had no scientific foundation that they could see.

Does it's use pay off?

87% of farmers said no, it's use does not pay off. The remainder felt that it's use did pay off. One grower explained his philosophy indicating that it was a long term project, and you had to know what you were using and the reasons for using it. There must be an overall program in place. It was not as simple as buying a product off the shelf. His aim was to bring his soils back into condition. At present he felt that his soils were in rehabilitation mode and this was expensive. Once they come out of "rehab" he hopes there should be a decline in inputs and cost. He said this approach had been proven in other crops but not in cotton yet.

How do you measure the benefits?

Visually in crop growth response and in gross margins.

Comparative replicated trials

Very few, if any comparative replicated trials have been conducted although many growers said that this is what they would like to see to provide good data on which to base their decisions.

CHAPTER 3: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. Credible information from independent cotton industry organisations on the benefits of commercial biological products,
2. Comparative farm trials needed
3. Standards and protocols to be set for soil and leaf testing

CHAPTER 4: VESICULAR ARBUSCULAR MYCORRHIZA (VAM)

Introduction

93% of growers have a basic understanding of VAM and it's importance in the uptake of phosphorus and zinc. There were a few however, who admitted they knew very little about it.

Current drought conditions, forced long fallows and the fear of long fallow disorder has heightened growers awareness to VAM and the possible consequences of the low VAM numbers. Some country has not been cropped for 3 to 4 seasons. In soils naturally very low in phosphorus VAM becomes a very important issue.

Growers tactics against long fallow disorder and low VAM populations include rotations, sacrificial crops, phosphorus and zinc applications. During the last cotton season one grower successfully applied VAM as a liquid injected side dressing 4 weeks after sowing resulting in increased nutrient levels in the plant.

Often crops suffering from long fallow disorder early season recover and produce quite respectable yields.

Does VAM affect compaction?

54% said no, 36% didn't know and 10% said yes. Reasons for the 'yes' response were that with low VAM numbers you produce a smaller bush which in turn returns less organic matter back to the soil. If the soil is alive and has lots of soil organisms/insects it is less likely to be compacted,

Do you need to know more about VAM and how to improve VAM populations?

48% of those interviewed said yes to more information on VAM. Their reasons included how to improve VAM populations, how to choose the right crop in rotation to enhance VAM numbers, the need for a procedure where soil can be sent away for testing (at the moment this service is not that good), a simple field tool farmers could use to measure VAM levels cheaply and so keep an eye on the situation and to what extent are early season VAM problems affecting yield. Is there a water injected inoculum that works?

28% said "maybe", and indicated that there is a lot of information already available.

24% said "no", suggesting they were ahead of the industry, they could go to the internet, refer to industry publications and/ or network within their own group.

CHAPTER 4: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. More information is needed about managing for better VAM populations
2. Better laboratory testing of VAM samples
3. Simple tool for in-field use to measure VAM levels
4. Information on water-injected inoculum
5. Knowledge on VAM problems affecting yield

CHAPTER 5: ENVIRONMENTAL ISSUES

Introduction

Twenty four percent of growers felt reasonably comfortable with environmental issues. The majority of these growers had no real problems, and indicated that their situation had improved considerably. They thought the industry was heading in a good direction with reduced pesticide use, better farming practices and reduced water use. Bollgard technology has taken a lot of stress out of management and social interaction with neighbours. A minority had nothing specific to say.

Fourteen percent of growers thought greenhouse gas emissions were a serious problem. Issues of concern included global warming and the impact this is having on the amount and frequency of rainfall with the subsequent effect on water and a farmers ability to produce, to remain sustainable.

Fourteen percent expressed some concern about nutrients, particularly the over use of nitrogen. At present a cotton crop may need 200 to 220 units of nitrogen to produce a ten bale per hectare or better yield. One grower stated *"Removal studies however show how much has been used by the cotton and there is still a fair amount unaccounted for. Evidence indicates it is not there for the following wheat crop. If it's not in the soil, not in the cotton, it has gone off farm. Where is it?"*

Other growers agreed *"Maybe growers need to be more efficient in satisfying the crops needs as it develops rather than applying all the nitrogen pre-plant."* They also mentioned that one day the environmental spotlight will focus on this and we will need some answers. *"In a way it's what mulesing has done to the sheep industry".*

Ten percent of growers were concerned about residual herbicides and nutrient run off, what this does to soil health and what impacts they have down stream. One grower referred to a report on the cane farming industry, which was blamed for nutrient run off and it's effect on the Reef. During the past ten years the industry has reduced fertilizer use by forty percent. These cotton farmers did not want to be responsible for nutrient/residual herbicides entering the river systems.

To a lesser extent growers expressed concern about water, water usage and maximising WUE, RR volunteers and escapes polluting water ways, neighbours properties and public land. One grower

believes he is seeing the effects of Bollgard cotton root exudates impacting negatively on soil biota.

Other concerns included spray drift, sodium, the use of harsh pesticides, stubble burning, problems with flax leafed fleabane and it's control, deep drainage, and the need for a system of measurement to provide indicators or benchmarks to provide evidence of what farmers have achieved over time.

What do you consider soil bio-diversity to be?

Most growers struggled to understand exactly what soil bio-diversity is.

Sixty one percent of growers focus on soil organisms suggesting there has to be a good balance of micro and macro organisms including fungi, working together to provide a healthy soil.

Eleven percent focussed more on a farming systems approach, trying to encapsulate all aspects of a farming system including farming system programs, cropping systems and overall management.

Seven percent talked about rotations, having a rich mix of summer and winter crops including legumes.

One grower suggested that in soils with good bio-diversity, stubble decomposes and does not cause trouble for the following crop.

There were a small number who felt they were not in a position to offer an opinion.

What would soil bio-diversity include?

Growers spoke about earthworms, bacteria, fungi, VAM, soil chemistry, organic matter and soil structure.

CHAPTER 5: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. Environmental effects of methods of fertiliser application
2. Better management/knowledge of residual herbicides and possible run-off
3. Benchmarking of environmental achievements

CHAPTER 6: MEASURING AND MONITORING

Existing cropping land

Do you monitor soil health issues yourself?

Ninety percent of growers conduct some form of soil health monitoring. Ten percent do not monitor at all.

Of those who did monitor, twenty nine percent targeted soil nutrient levels through soil testing. Two of these growers monitored compaction using capacitance probe data.

Twenty five percent made visual observations of the soil and crop by pulling up a handful of dirt and feeling and smelling it and simply watching and assessing the growth and development of the crop. If there are problems, efforts are made to diagnose and correct them.

Twenty one percent of farmers employed a more comprehensive soil health monitoring program, including visual, physical and chemical assessments. Yield is a major parameter. Visual observations are made of crop vigour, growth and development, and disease. Soil tests are taken for soil nutrient and organic carbon levels. Benefits of good soil structure are monitored using soil pits to assess compaction and infiltration. Capacitance probes are also used to assess compaction, infiltration and moisture monitoring.

Eleven percent rely on their consultant to monitor and keep them abreast of crop progress, and chemical and physical management.

The remaining growers varied in their approach, looking for good worm populations and trying to replicate the benefits of dryland no-till farming. One grower takes only organic carbon measurements because in his opinion these are the only type of measure he can trust. Another grower has actually started monitoring soil biota through soil samples and root analysis.

How do you measure soil health?

What are the key factors?

Yield is the major key factor in measuring soil health. Key soil structure factors include compaction, infiltration and internal drainage, friability and ease of tillage, waterlogging, feel and smell, organic matter and soil pits. Key soil biology factors include

fungi, earthworms, bugs and beetles, disease, organic carbon, decomposition and any shifts in soil biota populations. Other factors included: water holding capacity, water use efficiency, seedling and crop vigour, nutrition.

What tools do you need to measure soil health?

Growers offered the following suggestions: education, backhoe, shovel, GPS and decision support systems, EM surveys, good records, yield mapping, biological tests, and soil tests for nutrition.

Future cropping land

Are/have you developed land for cotton recently?

Fifty two percent of farmers have recently developed new cotton country or are planning to develop in the near future.

Do you do any soil testing prior to development?

Sixty percent of growers conduct some form of soil testing prior to development. For some it's a soil test for major and minor elements. For others it's the depth of top soil, plant available water capacity, the soil profile and soil variation. Others look at calcium, sodium and magnesium levels. A few use soil pits, some in conjunction with a consultant soil scientist.

One grower first cleans the country of native vegetation and stumps, then begins a dryland wheat program for two to three years to monitor in a dryland sense how the country performs. The country is then surveyed for irrigation, then cut and fill ratios calculated. If the cuts are too big, earth works are done to leave top soil on these heavy cut areas. Both cut and fill zones are soil tested prior to the first cotton crop and variable rate fertilizer applicators apply fertiliser according to the tests.

Would you consider taking soil health measurements before growing cotton?

Fifty percent of growers responded with a "maybe" to this question. Their hesitation revolved around reliability of biological testing procedures which are supported by good science, what was being measured and how this would benefit subsequent cotton crops. One grower said this was not high on

his priority list and he would need to be shown how it could benefit him.

Twenty eight percent said "yes" but gave no explanation for their response.

Seventeen percent responded with a "no", one grower saying that it would not impact on development and another saying the only thing he feels reasonably confident about is the physical health and sustainability of his soils, which over time has seen definite improvements in both soil structure and ease of working.

CHAPTER 6: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. Information on how to measure soil health, using: soil pits, EM surveys, yield maps, biological tests and soil tests
2. Credible information on benefits of biological tests

CHAPTER 7: SOIL STRUCTURE

Describe your philosophy on how you manage your soils' structural qualities. What are the key factors you use in achieving this outcome?

Compaction

All growers are well aware of the problems associated with compaction and have a soil management program in place designed to minimise and manage compaction. Management options include care of soils under wet conditions, machinery weight, controlled traffic systems, GPS technology and auto-steer pickers, minimum tillage, permanent beds, rotations and biological ripping, stubble management and organic matter accumulation, pulling plants out to look at root direction, monitoring salinity, Ca:Mg ratios and Na levels, a gypsum program, soil pits and references to SOILpak. Not all growers do everything listed above but all growers do have a soil management program in place, embracing varying amounts of what has been listed above.

Some growers using a 2:1 cotton/wheat or 1:1 cotton/wheat rotational farming system aim to maintain their permanent beds for nine or ten years before pulling them down, re-lasering, deep ripping and re-listing using GPS technology. Others regularly middle bust/side bust and rip furrows.

GPS technology has allowed growers to flatten beds to better manage stubble, confident that with GPS technology they will place the wheel tracks in exactly the same place as before. Other growers are ripping the furrows. Roundup Ready (RR) technology has aided in reducing the number of passes through country.

Dry harvests experienced during the past three or four years have been great in terms of compaction management but all growers are aware that a wet season could be just around the corner which could set things back a bit.

Stubble management and decomposition has been a problem for growers during the drought, particularly for those in summer dominant rainfall zones in relation to sowing machinery adjustment and modification.

Field architecture to prevent waterlogging

Seventy six percent of those interviewed had suffered waterlogging. Growers admitted it was a key event in a crops life, causing huge yield losses.

To alleviate the risk of waterlogging, to get the water on/off quickly, growers are laser levelling their country, increasing grade, removing localised hollows, shortening runs, increasing heads and the number of siphons used, re-designing tailwater drainage systems and increasing pump capacities. Growers believe these improvements can give an immediate return of between .7 and 1.2 bales per hectare.

Field architecture has been complimented by use of capacitance probes and weather data to ensure timely application of water and to avoid as much as possible, aggravating a possible waterlogging situation.

One grower is looking at overhead irrigators as a more economic option than field architecture to reap the benefits of reduced waterlogging and improved drainage.

Twelve percent of growers believed their country had good natural slope and drainage without the need to laser or redesign and twelve percent were not prepared to redesign their field architecture.

Prevent a decline in structural stability caused by poor water quality

Seventy five percent of growers have good water quality and are not worried about a decline in structural stability.

Two growers in the Lower Namoi said that their river water is salty. One uses overland flows complimented by river water. The other grower also harvests water off scrub country and is concerned about the EC levels of that water.

Three growers on the Darling Downs use a combination of river/creek and bore water. The bore water has greater than 2000ppm salt. These growers never store bore water and always mix bore with river to irrigate.

What references do you have to help you? Who do you talk to?

Ninety two percent of growers use references of one type or another.

Major references included SOILpak, consultant soil scientists, soil pits, consultant/agronomist/IDO, neighbouring farmers, field days/seminars, and the humble shovel. Those on corporate farms used company experience. Other references mentioned included CRDC, Qld and NSW DPI's, yield monitors, researchers, the Australian Cotton Grower magazine, the Crop Production Course and experience.

If you produce "key soil factor maps" do you also produce "soil repair strategy maps" and/or "cost of repair maps"?

50% of growers interviewed had yield monitors fitted to their pickers. Of these growers 60% were still gathering yield data. Some had plans in place to progress to the next step. 40% had moved on. Four growers had developed "key soil factor" maps including yield, elevation and EM survey data and were in the process of or had completed laser levelling their country, plus other areas of field architecture. Two growers had commenced variable rate fertiliser application. Another two were applying variable rate gypsum. Two growers had progressed to "cost of repair maps". There appeared to be a little hesitancy amongst some growers to progress beyond yield data collection.

Do you believe that the results of EM surveys can be used to estimate all of the soil quality factors that are relevant to cotton production?

Sixty one percent of farmers surveyed did not believe that the results of EM surveys could be used to estimate all of the soil quality factors relevant to cotton production. However they did say it was an excellent starting tool. EM surveys have a strong correlation to texture, which has a strong correlation to water holding capacity which has a strong correlation to yield. EM surveys can identify representative soil types which assist in capacitance probe locations. They can also help the farmer to place nutrition trials on a consistent soil type providing statistically more accurate and meaningful data. They can be overlaid on cut and fill data to help provide maps of key soil factors. They are an exceptional farm management tool for planning farm layouts, the location of storage reservoirs supply and tailwater channels and where to put drip and lateral move. Queensland irrigators are obliged to conduct an EM survey prior to constructing

storage dams. At the same time growers offered a note of caution. As one grower said,

"EM surveys are a good starting point, but its only a beginning, you need to drill holes, they need a lot of ground truthing...there are variations in the readings...and to understand the variations you have to drill a few holes and from these you learn a lot."

Fifty four percent of farmers interviewed have had their country EM surveyed. Forty six percent have not. Of the latter group thirty three percent have conducted EM surveys prior to constructing storage dams and/or channels.

Thirty six percent of growers did not know whether EM surveys could be used to estimate all of the soil quality factors relevant to cotton production. One grower said they could be used for this purpose.

Do you refer to soil survey information for your district that has been published by agencies such as CSIRO, State Government Departments, Universities?

Twenty nine percent have referred to soil survey information, seventy one percent have not.

Assessment of Soil Structural Qualities

Key points farmers use in assessing their soils structural quality include the following in descending order of preference. Soil pits, sodicity, yield, infiltration and internal drainage, visual observations, friability, compaction, capacitance probes, root activity, feel and smell, printed references, salinity, seedling establishment, shovel, plant available water holding capacity (PAWC), health of crop, waterlogging, organic matter and its decomposition. Other issues included quality of the product, air space, stickiness test for magnesium, pH, company experience, penetrometer, yield maps and CEC's.

CHAPTER 7: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. Advice on preparing and using "Soil Factor maps"

CHAPTER 8: CHEMICAL FERTILITY

Introduction

Key factors involved in growers chemical fertility management included soil tests (Done annually or bi-annually, occasionally multiple times through the season and sometimes once every three or four years), paddock history in conjunction with grower experience, tissue and petiole testing and on farm nutrition trials.

Growers nitrogen fertiliser application was based on replacement. There were those who were concerned at the large amounts of nitrogen being applied and the damage this may cause to soil biota, the environment and to organic carbon levels in the soil. Most nitrogen is put on pre-plant but there are those who are beginning to think split application through the season (for one grower: five times) maybe a better option. There appears to be a swing away from NH₃ to urea.

Farmers are now turning their attention to P and K as factors limiting production. Concern exists that the high levels of P and K in the soils are not reflected in the plant (soil rich/ plant poor). There were concerns about the relationship between Na, high pH and the tie-up of major and minor elements. Foliar fertilisers are being used in an attempt to rectify this situation.

One grower with P levels of 5ppm has spent the past ten years in a build up phase, lifting his levels to 18 – 20ppm with the ultimate aim of 35ppm. He is concerned that with Bollgard technology there will be a much shorter boll set and consequent nutrient up take period, requiring healthy VAM populations and available P. He is also concerned about low Sulfur (S) levels in his soil. Another with high S levels has found that applying the sulphate form of fertiliser always gives him a better result.

Dryland growers on the "Downs" are concerned about nutrient stratification (deep placement) under no-till.

Trace elements e.g. Zinc, Copper, Boron and molybdenum were also mentioned.

Some growers are using poultry and feedlot manure.

Tissue/petiole testing

Tissue testing was done by 32% of growers at up to three times a season.

Petiole testing was carried out by 36% of growers on a regular basis and up to five times per season. 19% tested irregularly, only if there was a problem. 19% have petiole tested in the past but for various reasons are not doing it now.

One big complaint with petiole testing was the turn-around time for return of reports.

There was a small group of growers who did not tissue or petiole test.

Soil test, how often?

67% of growers soil test annually. Two growers test on a zone basis within fields, one for benchmarking and one who is using variable rate fertiliser application.

26% of growers soil test prior to each cotton crop in the rotation or every two to three years.

One grower tests several fields each year, selecting good and bad areas then comparing the differences.

There are an increasing number of growers who are now using GPS technology to permanently locate soil test sites giving a more accurate picture.

Do you have concerns about the accuracy of results from commercial soil testing laboratories? If so provide details

71% of farmers had concerns regarding accuracy. Grower concerns included field sampling, interpretation, variation/consistency and that individual laboratories are not uniform. Farmers felt the best they could get out of soil testing was a trend line.

There was an undercurrent of mistrust, the suggestion/concern being results can be tampered with to the benefit of some of the larger integrated laboratories.

19% of growers were happy with their soil tests.

One grower was happy with the accuracy but concerned about calibrations long term. Methods of testing are changing and maybe the numbers are different to what they were twenty years ago when he used the Quantum test. Farmers need consistency so data can be compared over the long term.

For more consistent results, growers are now inclined to stick with the one laboratory and simply look for trends. One grower then relates these recommendations back to 'Industry' science regarding element replacement per bales harvested.

Two growers did not soil test.

Do you take samples in the same place?

72% of growers take samples in the same place.

48% now use GPS technology to locate sampling sites.

28% of growers simply take random field samples.

To what depth is your cotton soil tested comprehensively?

46% of growers test to 30cm. Three growers in this group occasionally test to 90–100cms.

42% test to 0–30cm, 30–60cm and 60–90cm.

11% do a 0–30cm and 30–60cm tests. One grower does a 0–30cm and a 30–90cm test.

Deep tests were for nitrogen and sodicity.

What is your impression of the meaning of "comprehensive soil testing for cotton"?

All growers indicated that a comprehensive soil test for cotton covered the major elements N, P, K and S and minor elements Zn, Fe, Mg, Mo. Five growers included organic carbon, three growers mentioned sodicity, two growers mentioned bulk densities and soil structural tests. Salinity, exchangeable sodium percentage (ESP), electrical conductivity (EC), organic matter, cation exchange capacity (CEC) and slaking and dispersion were also mentioned.

Is your selection of soil sampling sites influenced by the results of crop yield mapping?

42% of growers' selection of soil sampling sites are influenced by crop yield mapping. 58% are not. Three growers in this group have plans to commence selection of soil sampling sites by the results of crop yield mapping. Another grower now uses soil type from EM survey data.

Do you keep soil samples separate for analysis, or do you bulk the samples from a paddock prior to laboratory analysis?

Forty three percent of growers kept samples separate for analysis. Twenty six percent selected sites using GPS technology and took between four and ten sub-samples within a radius of ten metres of the site. These samples were bulked and a sub-sample taken.

One grower who kept samples separate, has EM surveyed his property and now samples zones of similar soil type. Another grower bulks the samples for each depth.

If you keep your top soil and subsoil analysis separate, do you map the results to produce maps of key soil factors?

One grower does this using GPS technology. Several growers said soil testing was very expensive and this acted as a deterrent to extensive soil testing.

Growers Fertiliser Regime

The table below attempts to list fertiliser use by 25 out of the 30 individual growers interviewed in this survey. Some growers applied gypsum as well as the above fertilisers, specifically to help lower ESP levels (Exchangeable Sodium). Sodidity is a problem on many of our cotton soils, both in the topsoil and subsoil. To help minimise the effects of sodicity, some growers have, together with other management practices, implemented a gypsum application program on their sodic soils. Rates of gypsum application were not mentioned, and timing varied from farm to farm.

Units are in kilograms per hectare unless otherwise stated

Nitrogen	Phosphorus	Potassium	Zinc	Sulphur
200	30	40	2.5	
220+18(MAP)	35		2.5	
200+17(MAP)	33		2	
220+24+33(MAP)	44-66			
150+17(MAP)+50 water-run urea, 1st 2 irrigations	33		2.5	
220	24		2.5 occasionally foliar	
100+20-30 post plant				
140+30 water run at flowering			10 units every 3-4 years	
200	50	20	Sometimes	
180+6(MAP)	11	20	7	8
80+8(MAP) 12t/ha manure	15	28		11
100		K as blend	4	
200+10 Starter Z manure every 5 years	24	50	1	2
150-160+manure				
180-200+8 Starter Z	17		1	2
100-130+9 Starter Z+50-60 before 1 st irrigation	19		1	2
180-220+10 Starter Z	21	Foliar	1	2
250	20-30	K as foliar	3	
220+10 Starter Z	21		1	2
180+14Starter Z+50-60 water run 1 st 2 irrigations	29	K as Foliarx5		
200-220,30% to 50% pre-plant, remainder water run/side dress	P as starter liquid fert. + biological P	K as starter		
180-200	30	50		A bit
200	30	50	2	5- 10
200	30	40		
220	30	50	2	

With higher yields, should nutrient levels be increased?

43% of growers believe there will be an increase in applied nutrition to cater for higher yields. The consensus was *"what you take off must be replaced."*

Growers were reasonably comfortable with N but were concerned with P, K and S and indicated they were increasing the inputs of these elements. Foliar sprays were mentioned as a cheap way of topping up K.

There was a feeling that recommendations are now made on 7.5 bales/ha when yields are now approaching 12 bales/ha. *"Without an increase in nutritional inputs is this sustainable into the future?"*

Two growers indicated that Bollgard is going to change nutritional management regarding higher nutritional demands of some elements during peak use at the flowering/boll filling phase.

43% suggested that increasing applied fertiliser was not the way to go. It was not the total amount applied but the way it was applied through the season. *"We need to be more efficient."*

Two growers said waterlogging and field architecture were far more important for them than worrying about high nutrition rates. Steeper slope, shorter runs, removal of hollows, increased head and redesigned tail-water systems to get the water on/off quickly, provide good drainage and an immediate return on money invested. Once this has been sorted out they will fine tune their nutritional issues.

What references do you have and who do you talk to?

Growers references included NUTRIpak, SOILpak, the old AFL Fertiliser Book, the Australian Cotton Grower, Cotton Conference, Trade Show, 'Industry' days, field days, Researcher—Ian Rochester, and other growers.

CHAPTER 8: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. Information on fertiliser recommendations for higher yielding crops
2. Information/recommendations for split applications during the season
3. Information on P and K limiting production
4. Deep stratification under no-till situations
5. Improvement in petiole testing
6. Interpreting test results or 'trends'

CHAPTER 9: EXTENSION SERVICES

What information do you presently get on soil health and who provides it?

Growers first response was that aside from structural and chemical issues they were not getting information on soil health and found it very hard to source reliable information. Farmers listed three sources of soil health information, the industry (CRDC/CRC), consultants and net-working with other growers.

It seems that growers rely heavily on the industry to provide this information. They have great trust and faith in CRDC/CRC. They look to CRDC for leadership and direction. They refer to the different publications CRDC distributes and to the well founded research based articles written by the research and extension team for the Australian Cotton Magazine as excellent, and speak highly about the research and extension teams for their effort.

Growers also rely on their consultants to provide technical information on soil health matters.

More experienced growers have their own networks established. They have their own groups. They speak to companies like Incitec, Advanced Nutrients, Bio-Nutrients and other commercial providers. They read the industry publications and keep in touch with the research and extension teams and private enterprise.

Are you satisfied/trust the information provided?

All growers said they were satisfied and trusted information provided but with qualifications. It depended on who provides the information. Growers trust the CRDC/CRC research and extension teams, and the New South Wales and Queensland Departments of Primary Industries, and their consultant/agronomist.

They felt that data provided need to be independent and supported by good science. Growers were very cautious about commercial information and that provided by resellers and salesmen. In relation to soil biology, two growers said they only go to those people they respect professionally.

One grower questioned whether conclusions made about soil biota at one location could be

extrapolated to other locations with their variations in soil type, clay type, history, rainfall patterns and cropping systems e.g. Bourke compared to Trangie.

Would you prefer other sources of information on how to assess soil health?

When asked this question growers response was "yes" provided it was credible, reliable and supported by good science. Once again they expressed trust in CRDC/CRC. Commercially driven people were treated with caution.

Soil biology was considered a bit of an unknown. The question was asked, *"are there good practices out there that we can employ? Who can we find who is knowledgeable credible, reliable and supported by good science?"*

What extension provisions would you like to see?

Growers highlighted five major areas in relation to extension provisions. These included measurement of VAM and measurement of other soil biota, SOILpak, nutrition and organic carbon. Other subjects mentioned included sodium, residual herbicides, greenhouse gases, managing sodic sub-soils and nutrient recycling.

Growers are asking for creditable, reliable, and scientifically rigorous procedures for measuring both VAM and other soil biota. In the case of VAM, to give an indication of what the population is prior to planting and for other soil organisms, if only for the major groups of organisms, what is present and what might be absent.

Benchmarking soil biota numbers was also requested. Growers said there was a need to be able to measure change. The problem is, results are not seen immediately. Growers must have faith in the system.

SOILpak was praised as a good manual and reference point for soil management. One suggestion was how could it be used more effectively, how to make it more relevant, suggesting that growers have moved on from the early days.

Growers once again raised the issue of the application of very large amounts of synthetic

fertiliser, particularly nitrogen and asked the question, "what impact is this having on soil health? Is it sustainable into the future?"

One grower suggested we need to fine tune the way we currently apply fertiliser to the crop ie. Instead of all in one application, apply it to fit in better with crop growth pattern. "To work with the crop rather than dictate to it".

Another grower spoke of the law of the limiting in relation to nutrition. Nitrogen has been addressed and we have some understanding of potassium, phosphorus and zinc. What element might now be limiting yield.

Another grower admitted we have been battling with a number of concepts for many years e.g., nutrition rates, legumes in rotation and sodium. He suggested we are getting better at it. We still don't have all the answers however he was comfortable that we are improving the soils. The friability of the soils is improving, sodium levels are reducing under minimum tillage. Soils that were nearly impossible to get a stand on four or five years ago or longer have now turned into beautiful soils. The cotton industry is certainly not punishing soils.

Dryland growers again pushed for work on deep placement of fertiliser on their no-till, direct drill systems.

Issues raised on soil bio-diversity included the relationship between VAM and nutrition, the need to trial biological products, the effect of residual herbicides on soil organisms and diseases particularly Fusarium.

The IDO network had strong support from growers. Having an IDO specific to a region, being able to establish a long term program, record results and follow up with on-farm meetings was suggested as a good concept. IDO's are an excellent way of extending information. They are probably the best vehicle for transferring the results of research and transferring information on from other farmers. All growers share the knowledge with an IDO in their area.

A grower from Mungindi would like to see the Mungindi Grower Group reformed. He also felt there was a problem as to whether the Mungindi growers came under Goondiwindi or Moree.

Finally there were a few who were very happy with the current situation. As one grower commented "I have no issues, our IDO is fantastic, we are kept up to date very well on soil issues, and other things. We've got some great people out there."

There was a plea from one area regarding soil health, requesting more information on what had been done and the provision of workshops which farmers could attend so that they can get back to the basics of understanding the soil.

Three growers mentioned organic carbon, one grower discussed the issue. Organic carbon levels can be measured in the soil. The problem is how can they be increased? Growers who have adopted a permanent bed/control traffic system and who incorporate all crop residues sometimes find the stubble decomposes very quickly. This is good in relation to reducing stubble management problems but were not sure in terms of organic matter for structure, compaction and increasing organic carbon levels.

Would you appreciate more information explaining what happens in soils. What issues would you like to hear about?

Ninety three percent of growers asked for more information on soil biology. Of these twenty eight percent did not elaborate. The remainder discussed a range of issues, including, a basic overview to provide a better understanding of soil biology, effect of farming practices on soil biology, microbial soil balance and the impact of rotation crops on microbial activity and balance, nutrient recycling and how soil biology relates back to nutrition, a better understanding of soil bio-diversity, understanding the balance between fungi and bacteria relative to soil health, and the effect of NH₃ versus urea on soil organisms.

One grower was very sceptical of the soil health/ biological push. He could not see how this was limiting his ability to grow good cotton crops. When time was limiting he did not need to be distracted by things he didn't see as helpful and so he just 'dropped the shutters'.

Are you aware of the Integrated Disease Management Guidelines (IDMG)?

68% of farmers were aware of the IDMG, 32% were unaware of their existence.

CHAPTER 9: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. More extension on: credible and rigorous methods of measuring VAM levels
2. Benchmarking of soil biota
3. SOILpak used more effectively
4. Nutrition needs and effects of large amounts of N
5. Other nutritional elements which may be limiting growth
6. Methods and timing of applying fertiliser, including no-till, direct drilling
7. Relationship between VAM and nutrition
8. How to raise organic carbon levels and its effect on soil: structure, compaction and organic carbon levels
9. Trials on biological products
10. Effects of residual herbicides on soil organisms and diseases
11. Regional workshops on managing soil health

CHAPTER 10: FUTURE SUGGESTIONS FOR RESEARCH AND EXTENSION

Do you fear that there will be soil health problems in the future? If so what elements will be affected?

Ninety percent of growers believe there will be soil health problems in the future, listing disease, nutrition, mono-culture farming, and nematodes as their main concerns. Sodidity, weeds, herbicide movement into the river systems and greenhouse gases were also mentioned.

Fusarium and BRR were listed as current threats. Growers at Emerald were concerned about the introduction of Fusarium into their regions. Apart from this, growers just felt there could be another problem on the way, suggesting that those most at risk are farmers on a mono-culture cotton farming system.

Considering the high yields being achieved, nutrition was also of concern regarding depletion of macro and micro nutrients from the soil bank to a point where it is unsustainable.

Growers were also concerned about the large amounts of fertiliser applied pre-plant to the crop. What effect is this having on the soil? Is there a smarter way of doing it? Can fertiliser be applied on a regular basis through the season to impact less on soil biota and at the same time improve yield potential.

Under dryland no-till/direct drill, deep placement of fertiliser is a matter of concern for dryland growers.

It was felt that growers who pushed their country too hard under a back to back mono-culture cropping system could end up in trouble.

Some growers had heard a rumour that bad nematodes were found at a couple of sites in the Namoi during the past season. *"We need to be able to identify and be ready to move on them if they do become a problem."* Nematodes become a vector for Fusarium. In the United States they caused yield losses, but if they bring Fusarium it would be devastating, particularly for the Macquarie Valley and south, more so than northern areas.

There was an air of optimism amongst 10% of growers. As one farmer said *"I don't see there will be problems in the future. We have some problems now. I don't see increases in any one thing, it's just handling issues as they arise."*

What issues would you like to see studied?

A range of issues were mentioned. These included a farming systems comparison between pull/rake/burn, BMP management and biological management to compare the effects on a range of soil health issues. Growers also asked for studies on soil biota, the impact that different rotation crops have on soil organisms and the balance of soil microbes, diseases, particularly Fusarium and how it establishes so well in our environment, benchmarking for soil biota, VAM, residual herbicides, salinity and sub-soil sodicity.

One grower suggested it would be good to have a link between chemical soil testing and biological soil testing. Simply by bringing the two groups together to talk. Research that helps this would be beneficial.

Education was raised by one region—requesting workshops to help growers better understand what is going on in the soil.

Why do you see these issues as important?

Yield, economics, viability and sustainability.

CHAPTER 10: SUGGESTIONS FOR RESEARCH OR EXTENSION

1. Information needed on the relationship between nematodes and Fusarium, and then how to manage this problem
2. Farming systems trial comparing 3 systems: pull, rake and burn; BMP; and biological management and their effects on soil health
3. Rotation crops impact on soil biota
4. Information about the relationship between soil biota and disease
5. Research comparing the 2 systems of testing: chemical soil testing vs biological soil testing
6. Regional workshops on soil biology

