ARE OUR FARMING SYSTEMS RUINING SOIL HEALTH?

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Our Current Cotton Farming Systems

The significant features of our current farming systems include:

**Monocultures of cotton and wheat.* A monoculture is the widespread repeated use of a single crop. The availability of numerous fields of genetically uniform host plants allows for rapid development of plant disease epidemics.

**Furrow irrigation and tailwater recirculation.* The movement of soil and crop residues in irrigation water enables the very efficient dispersal of pathogens from field to field around the farm.

**Reduced or minimum tillage.* The consequent retention of crop residues on or near the soil surface generally allows for increased survival of pathogens and facilitates the early infection of the subsequent crop.

**Permanent bed systems.* The careful positioning of a crop directly over the decaying remnants of the root system of the previous season's crop results in a more guaranteed and early 'introduction' of a pathogen to a host plant.

**Frequent machinery/vehicle/people movements.* The movement of farm vehicles and machinery, consultants and contractors enables effective dispersal of pathogens from field to field, farm to farm and from one cropping region to another.

It is widely recognized that "Plant diseases are a man-made problem." Our current farming systems are 'pathogen-friendly'. All of the pathogens that cause diseases of cotton are favoured by one, or in most cases, several of these farming system features. Our current cotton farming systems are ruining ***cotton*** health!

Soil Health and Soil Quality

Many definitions of soil health and soil quality are similar and it would appear that some regard the terms as interchangeable. Others suggest that 'soil health' pertains to biological functions of the soil while 'soil quality' is concerned with the physical and chemical functions.

Blumenthal (2001) suggested that a sandy desert soil and an acid-sulphate wetland soil could both be regarded as healthy soils in the context of the appropriate vegetation and wildlife communities. Both soil types, however, would rate poorly on a scale of soil quality based on the list of soil properties and attributes proposed by Slavich (2001) which include. protected soil surface and low erosion rate; high soil organic matter; high biological activity and biological diversity; high available moisture storage capacity; favourable soil pH; deep root zone; balanced stores of available nutrients; resilient & stable soil structure; adequate internal drainage; favourable soil strength and aeration; favourable soil temperature; low levels of soil-borne pathogens; low levels of toxic substances. There are many soils that do not have all or some of the qualities listed but still support stable and productive ecosystems and should therefore be considered healthy.

Doran and Zeiss (2000) defined soil health as "the capacity of soil to function as a vital living system within ecosystem and land-use boundaries, to sustain plant and animal production, maintain or enhance water and air quality and promote plant and animal health". Pimm (1984) defined healthy soil as being 'resistant' and 'resilient' where *resistance* is ability to resist changes resulting from imposed disturbances, and *resilience* is potential to recover following disturbance/degradation. These definitions indicate that soil function and responsiveness (within ecosystem and land-use boundaries) are the key components of soil health. A healthy soil is alive and responds and reacts to man's activities and inputs as well as to the vagaries of nature.

Why the Recent Interest in Soil Health

The soil health debate has attracted considerable interest in recent years. Unfortunately much of the debate has been 'data free' because the soil, and especially soil biology, is largely under-studied - with methods and techniques under-developed. One of the biggest benefits arising from the soil health debate has been the renewed interest in soil microbiology and the new approaches that are being evaluated for studying soil microbial activity.

Reasons for this increased interest in soil health include the following:

1. *Increased awareness that soils are alive and that the living component is important.* Burgess (1958) indicated that one gram (a teaspoon!) of a fertile agricultural soil contained 2,500 million bacteria, 700,000 actinomycetes, 400,000 fungi, 50,000 algae and 30,000 protozoa. Only 0.6% of the 2,500 million bacteria could be detected on dilution plates. Many soil microorganisms cannot be identified, have not been described and cannot be cultured! Populations vary considerably and rapidly under the influence of season, water, crop, cropping history, cultivation, etc. Big variations in the soil microbial population often occur between areas of the soil only 20-50cm apart. "Even in a small sample of soil which has been thoroughly mixed and then allowed to stand, large variations in the counts occur in a matter of a few hours." (Burgess, 1958) These soil micro-organisms play a vital role in crop nutrition and nutrient cycling, breakdown of crop residues and the carbon cycle, maintenance of soil structure, etc.

2. *Significant increases in the importance of diseases such as Fusarium wilt and black root rot which are caused by soil-borne pathogens.* Soils that have been rendered no longer suitable for cotton production because of high populations of the Fusarium wilt pathogen are capable of producing excellent crops of maize, sorghum, wheat, soybean etc. Such soils are still 'healthy' although their 'quality' has been downgraded somewhat by the presence of a cotton pathogen. Increasing disease pressure is a natural consequence of the imposition of a monoculture and the emergence of a disease problem is an indicator that the soil is healthy! The soil is resistant and resilient! When man introduced the Cactoblastis moth to control the prickly pear monoculture that had developed in south-eastern Queensland it was seen as a positive result. When nature introduced the Fusarium and black root rot pathogens to counteract the imposed cotton monoculture it was regarded as a negative outcome!

3. *Concerns about the reported decline in soil organic carbon and its possible consequences.* What is the significance of this decline? It is a consequence of the addition of fertiliser, aeration by cultivation and frequent irrigations that accelerates microbial decomposition of crop residues and leads to increased respiration and loss of carbon to atmospheric CO2. Is it possible to have too much soil microbial activity? Should crop residues be left standing so that they can't break down so fast?

4. *The activity of those promoting organic and/or 'quickfix' remedies for disease problems and soil conditions.* The proposed remedies include homeopathic, herbal, magnetic, multi-vitamin, multi-micro-nutrient, enzymatic, induced resistance and microbial treatments etc. etc. Some (not all!) of the information being distributed by these promoters has been dishonest and/or misleading. In a recent article it was claimed that Emerald cotton growers have a major 'long fallow disorder' problem (they don't!) which could be attributed to a " the only good plant is a dead one unless it is a cotton bush" attitude (Is that right?!). It was further suggested that the use of pesticides and herbicides reduced and sometimes eliminated the mycorrhizas (rubbish!) which then contributed to a calcium deficiency in the plant (more rubbish!) which explains why they have a Fusarium problem in Emerald! (They don't!).

Are Our Current Farming Systems Ruining Soil Health?

According to the dictionary 'ruin' means 'collapse', 'wreck' or 'complete destruction'. In reply to the question "Are our farming systems ruining soil health?" a soil physicist would say "No." We have generally learnt to avoid, manage and/or remediate compaction. Our soils are resilient and are able to recover from imposed disturbances. A crop nutritionist would say "No – but!" With our current fertiliser application and nutrient monitoring strategies we are able to identify and replace the significant nutrients extracted by our cropping – but soil organic carbon levels are low and the soil micronutrient stocks are not unlimited. A soil chemist monitoring salinity might say "No – except in some particular areas."

In response to the same question a microbial ecologist (P.A. McGee) replied "Farming systems alter the biological dynamics of soil, reducing **complexity and diversity**. In many cases this reduction need not reduce the **functionality** of the soil." (This means "Not necessarily" or "Not always"??) Diversity and function are two of the key issues in the soil health discussion and several new CRC/CRDC projects are now focusing on these areas of research.

Diversity and Function

Diversity implies differences, variations and variability in the population of soil organisms. Diversity is good as it allows for a more stable ecosystem. If diversity above ground is reduced or virtually eliminated by the imposition of cotton or wheat monocultures then it is expected that diversity in the soil microbial population might also be changed. Changed diversity does not imply reduced functionality.

For example:. The imposition of a Toyota monoculture on the driving public of Australia would result in significant reduction in diversity but all of the functions would be maintained!! There would still be vans and buses, trucks and utilities, 4WD's and sedans, etc. – Similarly under a cotton monoculture the biodiversity is reduced but it would appear that all of the functions are maintained. There are still mycorrhizas and nematodes, nitrifiers and denitrifiers, cellulolytic bacteria and fungi. etc. – (And – just as the Ford, Holden, Benz and Volvo zealots in the Australian population would seek to overthrow and undermine the Toyota monoculture so the Fusarium and black root rot sectors of the soil microbial population work to overthrow the cotton monoculture!)

The adoption of intensive farming practices does not necessarily imply reduced microbial diversity, activity and/or biomass. At a recent ACRI seminar Kieth Hutchison of UNE reported greatly increased microbial, micro-fauna and meso-fauna biomass in soil under fertilised introduced pastures compared to that in soil under non-fertilised native pastures. Perhaps the microbial activity under a cotton farming system with high fertiliser and water inputs might be a lot higher than expected? In any case, it is important to realise that the soil ecosystem (apart from one or two introduced pathogens), is still a native ecosystem, even after years of cropping with introduced plants.

Soil Health Indicators

Soil health indicators are cheap! They are called seeds! When planted and watered they proceed to integrate all of the factors contributing to soil health ie. soil biology, physics and chemistry along with the environment. These soil health indicators produce a report at the end of the season called 'yield' This report is confined to the current situation and cannot be relied upon to predict the future. However, monitoring the annual yield reports along with the mid-season (tissue analysis) reports will give an indication of long term trends.

When considering biological attributes of soil health alone it is difficult to identify indicators that are independent of the weather, the season and time. Despite this constraint, monitoring soil structure and/or the activity of specific functional groups (nitrifiers/denitrifiers?, cellulolytic organisms, mycorrhizas etc.) may assist with an assessment of the impact of various farming practices that make up our cotton farming system. One of the significant challenges facing the research effort is the development of techniques and the identification of indicators of soil health.

Can we modify our Farming Systems and Improve Plant and Soil Health?

There are no simple answers. It is very easy to suggest changes and modifications to farming practices but the limiting constraints are usually economics and practicality.

Plant Health

More diverse crop rotation strategies would alleviate some of the problems resulting from the widespread use of a monoculture but alternative, profitable, rotation crop options are limited. Perhaps longer rotations would be beneficial? (eg. Three years cotton followed by three years of wheat or some other non-host may provide significant control of black root rot – D.B. Nehl *pers. comm.*?)

Thorough incorporation of cotton crop residues after harvest would generally reduce pathogen survival. However, survival of the Fusarium wilt pathogen is favoured by early incorporation of crop residues. Incorporation of crop residues requires higher machinery inputs, reduces soil surface protection and may present compaction problems in some seasons. The retention of standing cereal residues may provide a better environment for cotton establishment.

Buried-drip irrigation would eliminate the tail-water and in-furrow dispersal of pathogens within fields and around farms. Buried-drip irrigation may also reduce the rate of residue decomposition by microbes thereby reducing the rate of soil organic carbon loss? An alternative (and somewhat difficult) approach would be the modification of furrow irrigation practices to eliminate or minimise tail-water except in rainfall events.

The possibility of off-setting the plant line and fertiliser placement by 10-12cm and alternating from one side of the bed to the other each season could be investigated as a way of retaining permanent beds but avoiding the plant line in the same position every season. Such a system would have the fertiliser applied along the previous season's plant line and the plant line above the previous season's fertiliser line.

Soil Health

The problems of reduced diversity and declining soil organic carbon could be addressed by switching to intensive pasture or more intensive and diverse cropping with less fertiliser and less water. The other options presented above as strategies for improving plant health would also contribute to improved soil health.

Some have suggested the regular application of compost as a soil health remedy. While there are obvious potential benefits, there are some problems with the dispersal of pathogens and the economics of applying several tonnes of compost to each field, each year (or every second year). Sourcing the thousands of tonnes of compost that would be needed would be almost impossible.

There have also been attempts to introduce soil microbe(s) and biological treatments developed and refined on completely different soil types and in other agricultural systems. The soils in cotton production areas have their own well-developed, well-adapted, native microbial populations and enforced microbial immigration/resettlement packages will seldom be successful.

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