Bio-responsible Farming: The quest for farming systems friendly to all especially the wallet!

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Take Home Message

- Intensive cropping systems rely on a high level of production management and prudent financial mangment to be successful, particularly in such a variable climate. Furthermore, such systems are increasingly reliant on agricultural chemicals. As well as being costly, the flow on effects of this reliance such as herbicide resistant weeds and changes to pest populations invokes thoughts about the long term environmental and financial sustainability of such a system.
- Alternative systems such as biological farming are gaining popularity in mainstream agriculture. While the intention of a “biological farming system” has merit, the methods promoted are subject to question with little scientific data to support their use.
- Such systems taken in their entirety appear unlikely to be economically sustainable, particularly on well structured and relatively fertile alkaline soils.
- Bio-responsible farming is proposed as a system that incorporates profit focussed best management practice of mainstream crop production along with some of the intentions of biological farming systems and other integrated weed and pest management strategies. It also incorporates all available technology.
- The term bio-responsible recognises a responsibility to the environment and a responsibility for the viability of the farm business.

Background

The recognition by many farmers that the current high input system of farming may not be sustainable in the long term has lead to an interest in alternative farming methods. Non-chemical systems such as “Biological Farming”, once considered only the realm of alternative farmers, are making a move into mainstream broad-acre cropping. The wholesale adoption of such systems, (sometimes at great cost), is concerning, especially given the lack of locally derived rigorous information to substantiate the claimed benefits. However, components of such systems have merit and could be incorporated into current farming systems to improve sustainability.

The Purpose of this paper:

This paper addresses three issues:

a) The challenges facing high input farming systems

b) How valid is biological farming as an alternative

c) Can high input farming and alternative methods be integrated?

Part A) Is "high input" cropping unsustainable?

The development of high input cropping

The farming system of the JSA client base and many across the Wimmera and southern Mallee is generally a crop intensive system, zero to minimal tillage (some more than others) with a high level of crop management aimed at maximising water use efficiency balanced with minimising risk and maximising profit. The crop mix varies and has evolved from the continuous cropping regime in the 1990s characterised by pulse crops and canola in rotation with cereals, to one that has become cereal dominant with some ley years (chemical fallow, pasture, hay) with less canola and pulses and a renewed emphasis on livestock. This change has been in response to the run of dry years and the need to manage resistant ryegrass (and the loss of chickpeas for a period of time).

A number of issues have emerged in this system particularly in relation to changes in weed, disease and insect dynamics that have resulted in an increase in agricultural chemical use. Some examples are given below.

Herbicide resistance

The current system relies heavily on herbicides for weed control and herbicide resistant weeds have evolved as a consequence, particularly annual ryegrass. Continued reliance on herbicides alone for weed control is unsustainable and is one reason why proposed alternatives (regardless of their validity) are attractive to farmers.

Increased foliar disease

Foliar disease pressure can increase as a result of stubble retention and more intensive crop rotations. The principal method for management of foliar diseases in crops is to grow resistant cultivars and crop rotation but the level of resistance available is not always adequate. In these cases, fungicides play an important role. Fungicide both applied to foliage and as a seed or fertiliser treatment has increased compared to ten years ago. The increased reliance on fungicides could result in fungicide resistance and the off-target effects on soil fungi are unknown.

Changes in pest dynamics

The insect and pest populations have also changed. Reduced cultivation and increased stubble retention has resulted in the escalation of pests such as snails, slugs and lucerne flea and has exacerbated mice numbers. This again has increased pesticide use.

Other examples, not related to stubble retention but to increased management include the prominence of Blue Oat Mite which have been unintentionally selected for as a result of the successful Timerite program for controlling Red Legged Earth Mite and a natural tolerance to insecticide dosages that will kill RLEM (Weeks 2005). Another example is a build up of slugs in Western Victoria, particularly where Fastac has been used as a bare earth spray which has reduced predator species.

Soil structure and changes in soil biota

While soil management has been important in this system with a strong focus on soil chemistry (fertility) and soil physics (soil structure) and a lesser focus on soil biology (except for recognising that soil organic matter levels drive nitrogen mineralisation and hence nitrogen fertility and the role of soil borne disease).

The move to a more intensive system if combined with stubble retention and soil amelioration has in many cases improved soil structure and general soil health. However, in other cases increased crop intensity, with a regime of cultivation has gradually eroded soil organic carbon levels and soil structure.

It is well established that management practices (e.g tillage, chemical use, grazing, compaction) will affect the dynamics of soil biota,(Gupta and Roget 2004), which in turn may affect crop health in both good and bad ways but because it's going on under ground and is difficult to measure it tends to be ignored. As the current system relies highly on chemical use, it is worth examining these effects on soil biota.

Effect of Chemical Use on Soil Biota

The continued reliance on chemical applications for weed, disease and pest control can have a negative affect on soil health. Examples include:

- off-target damage such as the destruction of beneficial insects
- -reduction of nodulation and nitrogen fixation in legumes (e.g Broadstrike,Spinnaker)
- -reduction of plant health and subsequent infection by soil pathogens (e.g Sulfonylureas and rhizoctonia) (Gupta and Roget 2004)

Herbicides vary in their effect on soil biota, some have very little effect and can in fact increase microbial activity (e,g glyphosate, Goal) (Van Zwietan 2004), others have a temporary effect that is reversible but there are some irreversible effects as a result of repeated applications.

A lack of understanding of chemical properties can also lead to misuse. For example Fastac (alpha-cypermethrin) is well accepted in the farming community as a friendly insecticide because it is a synthetic pyrethroid (SP) whereas endosulfan (thiodan) has a reputation as a "nasty chemical" to be avoided at all cost. In actual fact, endosulfan is "soft" on beneficial species whereas the SPs are very hard on beneficial species due to their residual length. Endosulfan does also have residue issues and is a restricted chemical so it should be managed carefully.

An improved understanding of the effect of all chemicals on target and non-target species (both at a macro and micro- level) is desirable.

These examples illustrate that the "high input" system has become even more high input and there is evidence mounting that the "solution in a drum" is not viable in the long term as it usually leads to another problem

Economics

The above examples focus on the production reasons why high input cropping is gaining a poor reputation, but it is no coincidence that this questioning is occurring at a time of significant economic hardship. It is also well recognised that focussing on maximising production without focussing on costs and profits can be fatal to a farm business.

Perhaps the interest in alternative farming systems is just a case of dissatisfaction with current margins and therefore a search for a "better" way. It is understandable that the lure of low inputs for the same output with the promise of being better for you and your soil is tempting.

However, the grass is not always greener on the other side of the fence, so it is imperative that alternative systems are evaluated with the same level of analysis that would take place for any major change to a farming system (e.g large capital investment in land or machinery, change in business structure, change in sowing system etc). Part B of this paper evaluates biological farming.

Part B) Biological Farming

An alternative to mainstream practice is to use an approach loosely titled 'Biological Farming" focussing on balancing soil biology, soil physics and soil chemistry. These methods tend to revolve around altering soil cation balance and the addition of soil biological additives such as humic and fulvic acid and cultures of micro-organisms.

This review focuses on a number of components of "Biological Farming" that are currently gaining momentum.

There are two main premises adopted by advocates of Biological Farming

1) Altering the balance of cations in the soil to specific levels will optimise soil health and plant growth (Albrecht Theory)
2) Soil health and plant growth can be optimised by having a specific balance of soil biota (known as the soil food web) and that this balance can be altered by the addition of food for biota and by the addition of cultures of organisms

   Both premises contend that on achievement of these goals, weeds, insects, disease and poor nutrition are less of a problem than in mainstream high input farming systems.

1) Albrecht Soil Theory

The Cation Balance Theory of Albrecht was developed in the 1940s in the USA and proposed optimum ratios between soil cations (Ca, Mg, K, Na) for plant growth.

While these ratios are generally accepted that they are optimum for plant growth, the theory has been disproved by most mainstream soil scientists as plants are highly adaptable and can grow in a wide range of cation balances. It is only when an actual deficiency or toxicity of a particular cation occurs, that growth will be significantly affected or if cation balance causes dispersive soils (e.g sodic soils) which therefore impacts on water infiltration and on plant growth.

The second flaw in the Albrecht system is that lime is a useful source of calcium in alkaline soils to amend cation balance. Albrecht assumed lime was soluble in alkaline soils but most main stream soil scientists dispute this, so adding lime to alkaline clays in the Wimmera will do nothing as it will not dissolve! (Note that free lime is often found on alkaline soils). There is no evidence that adding lime to alkaline soils improves production. There is evidence that unnecessary lime applications will but a dent in the bank balance. However lime is clearly important in the amelioration of acid soils.

The third point of contention is the method in which the cation ratios are derived. There is contention whether the analysis and interpretation methods of Albrecht are valid.

In Summary: The Albrecht Theory has very little credence in mainstream soil science and therefore should be treated cautiously.

2) The soil food web approach

The soil food web (SFW) is a term used to describe the balance of interactions in a soil biota community. This approach in biological farming, assumes that there is an ideal balance of soil biota for best plant growth and that this balance will vary depending on soil type, climate and production system. The process starts by monitoring soil organism levels and looking at relative balances and total amounts of each component and then prescribes a management program to address specific areas. (Table 1). Often this is done in conjunction with soil chemical analysis.

Table 1: Soil Food Web components considered by the Soil Food Web approach

Component	**Examples of remedial action**
Active Bacterial Biomass	Compost; starter cultures, food (simple sugars, e.g molasis, humic acid, fulvic acid)
Total Bacterial Biomass	As above
Active Fungal Biomass	Compost; starter cultures, food (fulvic acid)
Mycorrhizal Colonisation	Starter cultures, crop rotation
Protozoa (Flagellates, Amoebae, Ciliates)	Improve bacterial population to provide food source
Nematodes (bacterial feeding, fungal feeding, predatory, root feeding	Improve bacterial and fungal population to provide food source
Micro-arthropods	

Source: www.soilfoodweb.com.au

The monitoring of soil biota population has merit as certain organisms are related to specific functions (e.g nutrient cycling, stubble degradation) and there is mounting evidence that above ground observations can sometimes be traced back to changes in soil biota (Kirkegaard 2004; Gupta and Roget 2004) however, total reliance on this approach is questionable. Elements of this system are outlined below.

a) Testing and interpretation

-SFW assumes that there are established and proven thresholds for each organism or ratio (not the case on all soil types and climates).Some of the tests vary in reliability, are difficult to interpret and are therefore subjective (Abbot and Murphy 2004).The soil biota counts should not be considered without looking at soil nutrient levels and macrofauna (larger organisms like beetle etc) as in some soils like sands, macrofauna play a very important role as microfauna numbers are inherently low.The relative levels of all soil biota (micro and macro) will vary depending on soil type and on the climatic conditions at sampling. Moisture is required for microbial activity so populations change over time depending on moisture status. An assessment at one point of time could vary wildly if taken at another period of time. There is also spatial variability to consider as microbial populations can vary within millimetres (Gupta and Roget 2004).

b) Amelioration

After the soil test is taken and interpreted, a course of action is suggested which usually involves a series of additives. Soil biota is present to the tune of tonnes/ha. For example a soil with a bulk density of 1g/cm^3 equates to 1000 t of soil in the top 10cm of one hectare. With an organic carbon level of 1% this soil would have approximately 1.72% Organic matter (Baldock 2006) which equates to 17 t of soil organic matter present which includes the soil biota. What is the effect on adding the suggested ameliorants to this quantity of soil?

Compost/manure

Adding manure or compost to alter soil organic mater can provide food sources and additional biota if it is applied in large quantities in e.g tens of tonnes / hectare. It can also increase organic matter levels and improve soil structure as well as provide some nutrients. This is probably the most useful “natural” additive to soil.

Humic Acid

Humic acids (HA) are added as a source of carbon for fungi and bacteria. It is also claimed that they provide cation exchange sites on sandy soils and increase root growth and nutrient uptake. HA is also a chelating agent and there are claims that it will immobilise aluminium in acid soils.

The addition of amendments such as humic acid at 2-5kg/ha will not alter the amount of HA present as it is already present in quantities of tonnes to the hectare. For example, Baldock (2006) measured the humus component of the soil to range from 5 to 20t/ha in the top 10 cm in cropping districts of SE Australia. It is hard to these small additions making much difference to the overall carbon pool.

However, there are both claims and some scientific data to support the stimulation of plant growth as a result of HA applications. There are several theories of explanation including changing root permeability at the root-soil interface (rhizosphere) (Baldock pers. com 2004); stabilising of nutrients such as N and P preventing N losses or P fixation (Schwenke 2004) and improving the availability of Zn and Fe (Chen *et al.* 2004).

Fulvic acid

This is a derivative of humic acid. It is a strong chelating agent as well as a source of food for bacteria. It is claimed to be useful to add to herbicides to form complexes with the chemical that remains in the soil after application to prevent off target damage to soil biota or water ways. It is also reported to enhance fertilisers and herbicide activity but once again very little data exists to support this contention! Research is currently underway in the U.S.A investigating the potential for fulvic acid to reduce atrazine leaching. This could be useful if it can be proven.

For now, take care when adding to herbicides, particularly if the aim is to increase activity to reduce rates. Do a small area first and monitor crop safety. Fulvic acid could also reduce the residual activity of some chemicals so think about what you are adding it to.

Topping up microbial populations

The usefulness of adding introduced microbial populations to the soil has been doubted by mainstream microbiologists and soil scientists for a number of logical reasons. Introduced species are usually out competed by native species and populations do not establish well. The correct food source, moisture and temperature requirements may not be available. Australian soils with low carbon levels and our hot dry climate are considered a hostile environment for introduced microbes (Gupta and Roget 2004). There is no clear evidence that a more effective soil biota community is established based on the addition of soil microbes and the reduction of mainstream management practices (Kirkegaard 2004). Manipulating the soil microbe population without adequate soil temperature and moisture to drive population growth will be difficult, especially in our climate where soils are often cool when they are moist (winter)and dry they are warm (summer).

A better approach may be one where beneficial biota from a specific soil type and climate are identified and developed as commercial products. This approach is supported by the GRDC soil biology initiative and there are some products in the pipeline that may have merit.

c) The assumption that reducing mineral fertiliser will improve soil biota

The assumption that soil biota structure will be improved by reduced fertiliser was disputed by Ryan (2003) who found that the P deficiency was a limiting factor affecting soil biota on organic farms on acidic soils in NSW. In this case, the lack of P fertiliser was inhibiting soil biota. Bunemann and McNeill (2005) found that the availability of carbon substrates had more effect on soil biota than nutrients such as N and P. There was no clear evidence of adverse effects of mineral fertiliser on soil biota but if their use caused an increase in soil acidity then that did have an effect. There is a danger that going down the path of replacing mineral nutrients with biological additives will mine soil nutrient reserves but this may not be evident on alkaline clay soils for several years

d) The assumption that all pesticidse are bad for the soil

As mentioned earlier some herbicides can actually increase microbial activity and releases nutrients, therefore it is important to know which pesticides have negative effects on the soil and act accordingly rather than assuming all is bad! A useful review is provided by Van Zwieten L. 2004.

e) Using Brix meters to monitor crop health

The measurement of Total Dissolved Solids by a Brix meter mainly measures soluble carbohydrates present in plant sap. This is not a new concept. The relationship between soluble carbohydrates and nitrogen has been used for several years to determine if factors other than nitrogen are limiting growth. Brix meters do appear to indicate changes in plant condition but the reliability of taking a sap measurement as sap content fluctuates each day is a concern. This is an area that warrants further investigation.

In Summary

The concept of monitoring soil biota has merit, the concept of looking after soil biota by watching what you put in has merit, but the approach for amending soil biota balances has been questioned by mainstream science. It is also concerning that the soil food web premise and resultant remedies were developed for soils and climates with higher levels of soil carbon and higher moisture levels than in our own environment. It is hard to see how this information can be easily translated. The role of humic and fulvic acid in nutrient availability and chemical sequestering is worthy of further investigation. The claimed power of these additives is a concern though and reducing fertiliser or herbicide rates due to adding humic or fulvic acid needs further testing.

Biological Farming : The Verdict

The main message is buyer beware and until robust evidence exists it is difficult to accept the premises outlined above. Anyone considering adopting this system should conduct an economic analysis as you would for any other inputs. It could be a costly exercise if it doesn't work! However, components of these approaches could be transferred to mainstream farming if they are proven. The final part of this paper considers such a proposal.

C) Is there a more balanced approach? Bio-responsible Farming

The current exposure to alternative farming techniques does remind us that current practices are not totally sustainable and that there is a need to become somewhat "greener". It makes sense to use agricultural chemicals responsibly and safely and at present the industry is probably guilty of overuse. It is also obvious that we cannot put our heads in the sand about herbicide resistance. We should also be aware that soil is a finite resource and needs to be managed well, particularly soil organic matter and soil carbon which is ultimately the engine room for our productivity. While the intention of "biological farming systems" has merit, the methods promoted are subject to question with little scientific data to support their use.

Can we however have a system that incorporates the intentions of biological farming with best practice mainstream management to improve long term sustainability and profitability? I call this **bio-responsible** farming. This recognises the need to observe the effect of management practice on soil biology and also recognises that we have a responsibility to the environment and that we are responsible for the viability of the farm business. It also incorporates all available technology. This is not a lot different to what we do now, except that it is a more considered approach and requires more monitoring and knowledge. It will not be easy!

These are some suggested components of bio-responsible farming. The list is certainly not exhaustive and the system should develop as our knowledge continues to build. Some components are futuristic as the research is still under way. This summary essentially has a cropping focus but the principles could be extended to businesses where livestock plays a major role.

Business and Risk Management

- Whole farm business financial analysis
- Profit focus
- Tailoring the farming system to climate risk and likelihood of production variability
- Using decision support tools including climate risk mangment tools to assist with informed decision making
- Best practice price risk management for commodity sales
- Variable and fixed cost monitoring

Rotation

- Diverse and flexible: Less intense crop rotation (60-80%) with hay, green manure, chemical fallow and/ or pasture making up the rest and increasing crop intensity when season or prices allow.
- Opportunistic and flexible approach toward crop choice and livestock.
- To increase diversity, living plant material in the non-crop phase (pasture, green manure) is preferred to fallow.
- Willingness to rest paddocks that need a rest, in terms of soil fertility, soil health or weed burdens.

Tillage System

- Minimal Tillage (preferably but not necessarily no tillage as strategic cultivation may be required for integrated weed management)
- Stubble Retention where possible (occasional burning may be require for IWM and IPM)
- Flexibility

Soil health

- Use a nutrient balance approach as well as monitoring soil nutrient levels
- Maximise soil organic matter
- Monitoring of soil biota as a signal of soil health (if good guidelines and testing methods exist)

Crop Management

- Timely management of weeds, pests, disease and nutrients if required to maximise water use efficacy and yield potential

Livestock Management

- Profit focussed best practice livestock production that compliments the cropping system

Crop protection

- Utilising integrated management principles for pests and weeds:
- Improved knowledge of weed and insect biology
- Reduce weed seed banks
- Use several tools for control
- Improved knowledge of beneficial insects
- Monitor populations and observe established thresholds if they exist rather than a zero tolerance approach (particularly for pests)
- Use of softer chemicals where possible and minimise harsher chemicals where possible
- Use “seed dressings” instead of soil applied insecticides where possible
- Better awareness of chemical properties and their effect on human and soil health
- Use of additives to minimise off target effects of chemicals if proven to be valid

Precision Agriculture and New Technology

- Monitoring growth and yield to identify variations.
- Variable rate, weed seeker and/or direct injection technology to target management to zones within a paddock if significant variability exists which could reduce some inputs.
- Inter-row sowing for trash management and soil borne disease mangement
- Utilising guidance technology to maximise efficiencies of operation

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