Nuffield Farming Scholarships Trust

The Young Nuffield (Bob Matson) Award

Soil and crop nutrition

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Contents

Executive summary

Having visited the oldest soils in the world in Australia through to the youngest in Argentina and Brazil I have seen how soil should be treated, plant nutrition administered and soils worked plus the benefit of these practices on profitable farming. I have carried out many trials on my own farm which are ongoing and have had excellent results . These are changing the way I run both my own farm and our contract farms and improving their profitability. The results I am experiencing are living proof that the practices I have seen around the world working in this country.

In Europe the art of good soil husbandry is being lost in favour of a simplistic, one size fits all, to be treated as a chemistry set approach. Current arable practices of removing copious nutrients and replacing but a few, baling and burning organic matter as straw - particularly in power stations - and failing to replace it, plus running big heavy machinery over the ground to force it into a seedbed all need to be addressed if profitable arable farming is to be possible for the next generation.

There is a need for better and more rounded education in soil and crop nutrition, from college education through to advisor level and the press.

Incentives to take more of an interest in soil health and good crop nutrition could be offered through the ELS and HLS schemes because not all farmers perceive these techniques as having a direct link to their bottom line.

The result of my worldwide education and research has been for me a:

- 35% reduction in the use of phosphate fertiliser
- 25% reduction in nitrogen fertiliser
- 90% reduction in potash
- Increased use of foliar feed nutrient products
- The use of green manures before spring barley
- The production and application of ‘proper’ compost.

Background

I am a 5th generation farmer's daughter from Hertfordshire. From the age of 13 I have wanted to become an agronomist. I picked my GCSEs and A levels to complement my aim and this got me a place at Harper Adams where I achieved an Honours Degree in Agriculture and Crop Production. I spent my first summers at Harper working for CPB Twyford (now KWS) seed breeders and my placement year and final summer working as a trialist for Syngenta. I was offered a job with ProCam Agriculture as an agronomist when I left Harper in 2006, gained my BASIS and FACTS qualifications, and have been establishing my customer base ever since. I now walk 14,000 acres of combinable crops across a range of soil types for a variety of customers.

In conjunction with the development of my agronomy career, in 2004 I took over the office admin work for our family farm and contracting business. Over the last seven years my role on the farm and within the contracting business has increased to now running the business in partnership with my father. I currently split my time between my job as an agronomist, running the family farm and growing the contracting business.

My placement as both agronomist and farmer encourages me to get involved with all aspects of crop husbandry. I find the easiest farms to work on are those with the most holistic approach to farming. Good, farm level, soil and nutrition advice does not seem very available on farms in the UK and I found neither my clients nor my company very keen to get too deeply involved with such advice.

This led me to begin doing my own research which in turn led me to apply for a Nuffield Scholarship in 2009. I hoped this would enable me to investigate the relationship between soils and plants and the obvious benefits of treating these elements of farming as a whole.

2. Introduction

Soil is fundamental to all life on earth. We cannot produce food without it. But in East Anglia we seem to be growing a lot of blackgrass in it. As an agronomist I started to question why, and why it was worse on some farms than others and in some areas more so than others. Why were we all talking about how to control blackgrass once you had it – shouldn't we be talking about how not to have it in the first place? Why was no one discussing this?

One of my clients in Hertfordshire used a top quality compost on a field badly infested wih blackgrass. We treated the field with a pre emergence herbicide. Some of the anticipated blackgrass came up in late November but by March it had disappeared, requiring no over spray. A field across the road, farmed by the same farmer in the same way, had received the same pre emergence herbicide and now needed an overspray – could it possibly be the compost that made the difference?

I needed answers and my agricultural degree, BASIS and FACTS qualifications weren't helping at all. So I hit the books and internet for answers and applied for a Nuffield originally to look at 'Alternatives to inorganic fertilisers'. The study title was because the field that originally inspired my subject had only received half of its intended nitrogen application following the compost application. But I changed that title to 'Soil and Crop Nutrition' as I discovered more.

The soil of the Paraguayan Chaco

I visited Mennonite farmers in the Paraguayan Chaco, a sandy, desert-like region of central South America where soybeans were growing with no irrigation in pure sand (see Figure 1). I also visited Australian farmers near Adelaide growing cereals, soybeans and lucerne in non wetting soils (sands which repel water) and on ground being encroached by salination. These farmers were making a profit in extreme conditions with no government subsidisation to fall back on. The attention all of these farmers paid to soil and crop nutrition was clearly vital to their survival; they were using and adapting both new technology such as micronutrient formulations and crop testing methods plus long standing good agricultural practices such as adding manures which have first been turned into compost, thus preventing weed and disease cycling, and lock-up of nitrogen on application.

Spending time with farmers in such environments was a humbling experience and has led me to analyse our practices in the UK and Europe and to try to understand:

- How we have come to be so dependent on manufactured inputs?
- Why have we become so devolved from basic good agricultural practices?
- Why do we think our current practices are sustainable?
- Why if our system is so good can we not produce food as cheaply as other parts of the world who are unsubsidised?

These questions may seem 'big' and going off topic, but it is vital to understand our culture and history to help find the pathway forward.

To see where we are going we must first look back to see from where we have come.

2a. Where have we come from?

Farmers across Europe have accepted subsidy schemes since their first inception. It is easy money; however it was never a sustainable system and should have been dissolved on the emergence of ‘milk lakes’ and ‘grain mountains’ in the 1980s. Our healthy subsidised bottom lines have distracted us from world commodity prices and allowed our government to prop up unhealthy businesses which would have failed in any other sector – preventing the entry of fresh, inventive thinking. Since decoupling and the reduction of Pillar One we are gradually being launched onto a world stage of commodity production that our government has ill prepared us for, leaving us scratching our heads wondering how other countries have such low costs of production when ours are so high.

The answer - survival of the fittest.

Subsidisation has bred a culture in European farming of taking the easy road – selling straw for burning in power stations for cash, for instance, is short term gain – a move Southern hemisphere farmers simply laugh at: ‘sell my organic matter and nutrient store for burning just to have to pay to replace it?’.

European farmers have some of the highest input usage in the world (see table below) and it’s increasing. So have yields gone up in the last ten years to mirror this? No, they’ve hardly changed. So why has our cost of production outstripped the minute yield increases we have seen? – our ability to afford the inputs? Why are we just starting to see agricultural chemicals diverted from distribution in the UK and Europe and sent to South America instead? Because the South Americans are just starting to be able to afford these products and in much larger quantities than the European market.

These factors have resulted in European farmers not questioning research - where does it come from? Who sponsored it? Can I trust it? Does the sponsor have an ulterior motive? Instead manufacturer sponsored research has become accepted and practices that suit them have become a matter of course.

Kg of pesticide active Ingredient used / ha

Yr 2000			**T of Product**		
	Brazil	**Ireland**	**New Zealand**	**Germany**	**UK**
Insecticides	19452	55	289	1380	1657
Herbicides	36775	1289	2366	16610	10835
Fungicides	6203	444	763	9375	4862
PGR's	441	132	129	2141	3149
Total	62871	1920	3547	29506	20503
Arable land Area ‘000 ha	57700	1077	1500	11804	5876
Kg pesticide /ha	1.1	1.8	2.4	2.5	3.5

Source (FAO: 2000)

Take orange wheat blossom midge for example. The East Anglian wheat bowl suffered badly from this in 2007. Many milling wheat crops were affected and many acres had to be treated with Dursban to deal with the pest. Dow, who make Dursban, set up a monitoring scheme for the following year and produced traps with pheromone attractants inside to help farmers and agronomists decide whether or not to spray for the pest. There has not yet been a year since 2008 - when the service first started - when traps have not been found with 'sufficient levels of OWBM to treat' and an email sent to all agronomists that levels have been reached in some area or other.

I use spider's web analysis for OWBM trapping – no attracting of the pest, just a natural monitoring method, and I have rarely seen levels sufficiently significant as to need treatment. Yet I know plenty of farmers who *have* treated for the pest during this period. Why did we allow the chemical manufacturer the power to decide if the product should be applied?

During this time we have allowed many of our truly independent research facilities to close. I visited a group of Australian farmers in New South Wales who had set up their own trials and research group. This empowered the farmers, giving them the information they felt they needed to make impartial decisions about input usage and cultivation techniques.

Soil and crop nutrition has suffered the most under this system. With only machinery manufacturers and fertiliser companies doing any research into the area the results are too biased to fairly consider. We are a small country and it suits the fertiliser dealers very nicely to provide a small selection of products assuring us they'll do the job: that granular urea will do the same job as a liquid formulated nitrogen and for the right p/kg of N we are willing to agree. Yet we all know the granular will suffer much higher volatilisation losses so we'll either need more of it or get less benefit from it, but the dealer breaks it down to a basic p/kg of N and we're sold.

While we've been receiving that subsidy cheque our focus has been redirected and our guard down. We have allowed the power to shift from our buying power as a customer for the right product at the right price to the manufacturer's selling power, telling us what is the best product for them and what they will be prepared to sell it for.

On the one hand we are happy to 'see what we can get away with' in terms of cutting cultivation costs, rates of chemicals, soil sampling etc. On the other we are happy to spend, spend, spend on the machinery to carry out these cheaper cultivations, the products for which to lower the rates and the nitrogen fertiliser to grow lush greenery. Now which hand has more pounds in and who is really benefiting from these 'cost saving' measures?

2b. Where are we now?

To help explain the situation farmers in the UK find themselves in regarding soil health and crop nutrition programmes I first want to describe six stereotype groups of farmers. For this purpose I am excluding-subsistence farmers in developing countries. I am referring to the 'professional farmers' from developed nations.

1. **The Subsidy Farmer**: would no longer be farming if it were not for government intervention. This farmer relies on

assistance and makes little move to increase the farm's profitability. This farmer can be found across Europe and in the corn belt of North America.

2. **The Environmental Farmer**: found only in Europe. This farmer has increased the farm's profitability by maximising any return offered from government incentive schemes such as countryside stewardship, ELS and HLS.

3. **The Lifestyle Farmer**: Found throughout the 'developed world'. This farmer is happy to forego some profit/productivity to satisfy his personal hobbies. He is likely to have income from diversifications into enterprises such as urban and commercial property, whilst also 'profiting' from steps 1 and 2.

4. **The All Out Production Farmer**: Also found throughout the 'developed world'. This farmer eats, sleeps and breathes yield, inputs, shiny metal and more acres. This farmer has probably 'diversified' into more farming through renting land or contracting.

5. **The Southern Hemisphere Farmer**: I met this farmer in parts of Africa, Australia and New Zealand. With non subsidised production, this farmer cannot afford unproductive acres for any reason. Crop failures can mean bankruptcy.

6. **The South American Farmer**: As a southern hemisphere farmer with the burden of huge government imposed export taxes a productive acre without a crop for 12 months is not an option. The slickest and most efficiently run farm businesses I have observed anywhere in the world were in South America

I myself am a number 4, thinking before my Nuffield that I was at the top of my game. Now I shall strive to push up a level.

Consider how the removal of any government subsidisation would reconfigure this chart. I would urge all farmers to assess critically where they personally fit, why they are there and if there is any reason for an individual to want to change where they fit. In no way do I mean to criticise any farmer for their place on this 'ladder'. The motive which moves us out of these boxes is why we are where we are. Personally I want to become more profitable to pay my relatives out without halting the progress of the business, and in the future to buy more land to farm. So I want to become more efficient to make my repayments - I have a reason to want to move up.

Looking at this ladder in a UK context, an analysis of soil and crop nutrition is vital to understanding both where we have come from and where we stand today. There may still be the odd farmer not even analysing his soil at all at this point.

Category 1 farmers in the UK today are still only performing soil analysis for grain quality assurance scheme purposes. They are carrying out these tests as infrequently as possible to save money and simply applying the fertiliser as per their predecessors. Cultivations techniques are static and historic.

Category 2 farmers are probably taking 'W' pattern soil samples for P, K, Mg and pH, one per field every four years and using a FACTS qualified advisor to create an RB209 based recommendation for any necessary application of these nutrients. These farmers have probably adopted a min till option in their rotation based on a single machine and will use it irrespective of soil conditions at the time.

Category 3 farmers have probably progressed to GPS soil mapping for pH, P and K and are making variable rate applications. Sulphur and nitrogen are applied according to FACTS qualified RB209 based recommendations and some trace elements may be applied based on visual analysis by the agronomist. This farmer probably has a broader range of cultivation equipment including ploughing, a range of min till equipment and has possibly tried direct drilling. This farmer tries to tailor the cultivation to the conditions at the time.

Category 4 farmers have started to push the use of modern technology not only to variable rate lime, P and K but to look at varying N also. S is used as standard. Leaf tissue and sap testing are also used to monitor the crop's health. These farmers may use aids such as depth probes or penetrometers to aid cultivation depth and machinery type. These farmers utilise a wide range of cultivation equipment and are prepared to change their plans as soil conditions dictate.

As a group **Category 5** farmers are more often than not trying to conserve moisture and avoiding cultivation and prefer direct drilling techniques. Fertiliser and seed combination drilling is standard. Drilling is not carried out until the soil moisture has been assessed and deemed sufficient to sustain a crop. If this cannot be confirmed the farmer will not drill.

Category 6 farmers make extensive use of contractors. At the time for cultivation/drilling the farmer will test the soil and - often in conjunction with a soil advisor – then decide on the contractor with the most appropriate machine to carry out the work.

2c. Where are we going?

There are two possibilities:

Option A – continue

Most farmers will continue to be led by advertising and industry fed research. The cost of production for these farmers will continue to increase with little or no yield benefit. If subsidisation is removed these guys will be in for a truly tough economic time.

Option B – question

Some farmers are beginning to see the wood for the trees and question what will be the economic return on product 'X'. These farmers are spending more time on Cost:Benefit analysis before making a decision. Information for these farmers is the limiting factor. Once you start to doubt industry funded research there isn't much to go on in Europe. Obviously there are the Research institutes such as the John Innes and Rothamstead Research Institutes; yet however excellent the science coming from these Institutes is, it is left to the individual to interpret how it might actually be applied to real farming.

There is also a fundamental flaw in basing too much real life practice on this science as all top notch scientific experiments are performed in the linear plane – where one element is researched in the abundant presence of all others – particularly in the case of crop nutrition. Real farming is obviously not like this. I have yet to see a soil or tissue analysis where only one nutrient is deficient. So for a farmer non linear experimentation is the most important but also most unavailable source.

3. Progress

Dynamic soil nutrition advice did not seem readily available in the UK. Just after I was awarded my Nuffield Farming Scholarship one of my clients handed me a book – 'Hands on Agronomy' by Neal Kinsey - and I started to read. A lot of what Mr Kinsey wrote made sense and agreed with things I had seen in the field. I ordered all the authors and publications Neal referred to in his book and have spent my time since then reading these and other recommended texts to build for myself a more comprehensive understanding of soil and plant physiology, biology, chemistry and physics.

Neal's book made a huge impression on me. I contacted Neal to try and meet up with him and visit some of his customers – he suggested I join them on a small, four day course he held in Missouri, which seemed a good place to start. The course included a farm visit every morning before the tuition began. I was therefore able to see some of his theories and methods being put into practice with good results. The other delegates on the course were all customers of his so I was able to find out what techniques Neal had used in a variety of situations and what the outcomes had been.

Neal's methods are based on the research and experiments of Dr Albrecht, an American soil scientist. The basis of Albrecht's work was to look at crop nutrition holistically – as humans look at their nutrition. Plants require many nutrients to grow and these all need to be considered by farmers. The relationship between the nutrients as chemical elements needs to be understood if good advice is to be given to farmers about crop nutrition. Knowledge of their interaction in the soil can be vital to explaining what is available to the plant and what is not and how that might be rectified.

The key points I learnt from this course and my research, which I believe are fundamental to offering adequate nutritional advice, are highlighted in the following sections, 'Fertilisers' and 'Nutrients'. (See chapters 4 and 5 respectively).

4. Nutrients

Elements in a wheat plant : percentages required

Element	Common Name	% Requirement in a wheat plant	Available forms
O	Oxygen	45	O_2
C	Carbon	44	CO2
H	Hydrogen	6	H+
N	Nitrogen	2	NO3-, NH4+
K	Potassium	1.1	K+
Ca	Calcium	0.6	Ca++
S	Sulphur	0.5	SO4--
P	Phosphorus	0.4	H2PO4-, HPO4
Mg	Magnesium	0.3	Mg++
Mn	Manganese	0.05	Mn++
Fe	Iron	0.02	Fe++
Zn	Zinc	0.01	Zn++
Cl	Chlorine	0.01	Cl-
B	Boron	0.005	BO3--, B4O7--
Cu	Copper	0.001	Cu++
Mo	Molybdenum	0.0001	MoO4--

Elements in a wheat plant : percentages required

First we need to take a fresh look at the 'major nutrients.' What we actually need to think about is the 9 elements that make up the majority of a plant, for example as illustrated in the table below for a wheat plant. Oxygen, carbon and hydrogen constitute 95% of a plant's total elements and we assume adequate amounts come from the soil and air without our involvement – just bear the section on soil structure in mind.

The next biggest group is nitrogen and potassium, totalling 3.1%. Nitrogen is required little and often by the crop throughout its growing phases. Nitrogen is the world's most over used nutrient. It can now be applied at variable rate by an N sensor (superior to satellite imagery systems as it is real time and based on a chlorophyll measurement not historic general reflectance). I have conducted many nitrogen trials on my farm and am satisfied that through using a more balanced approach to crop nutrition significant reductions in the quantity of N applied per tonne of crop produced can be made.

The amount of potassium in the soil and its ratio to phosphate affects broad leaved weed levels. If the P:K ratio slips below 1:8 then herbicides may no longer be effective. Potassium is required in both the autumn for winter hardiness and spring for stem strength and fruit set. K can be variably applied from GPS soil maps – on deficient soils this should be done in the spring and a K based starter fertiliser used in the Autumn.

Calcium, sulphur, phosphorus, and magnesium are the remaining major or macro nutrients in that order. UK agriculture regularly recognises phosphorus, applied as phosphate which is vital for photosynthesis and rooting and calcium (measured as hydrogen ion content by pH) as nutrients worthy of concern, recommending treatment with lime on low calcium soils and phosphate fertiliser often applied variably from GPS mapping. As with K, phosphorus should be applied during the spring major growth phase to be efficient. However if soils are very deficient an autumn application as a starter fertiliser can significantly boost the rooting of winter sown crops.

Sulphur is vital for palatability, seed production, and nodule formation, and adequate levels work as a natural insecticide in the plant. Sulphur use is becoming 'normal' in oilseed rape crops; however there is still some way to go in cereal crops – largely because historical industrial deposits are satisfying crop needs. Sulphur should be applied early in the spring as it can take up to four months for most man made fertiliser forms to be fully taken up by the plant.

The final major nutrient historically overlooked is magnesium, needed for chlorophyll production and nitrogen regulation. From my experience of GPS soil sampling in East Anglia I rarely find a soil with sufficient magnesium levels. Mg foliar feeds can give the most cost effective results where levels are low. Excess magnesium can be obvious without a soil test: Mg tightens soils, an excess can make them sticky and when dry causes them to go hard. Conversely, calcium loosens soils: which is where a product like gypsum is good for flocculation of a high Mg, low Ca soil.

Ensuring the above nutrients are available in adequate but not excess amounts provides the initial building blocks for good crop nutrition. These elements should be dealt with and mastered before worrying about micronutrients (unless deficiencies are major, such as manganese on very organic soils). In conjunction with soil sampling for the above nutrients, leaf tissue or sap tests should be regularly carried out during the rapid growth stages of a crop to ensure all the major nutrients are sufficiently available. Ideally taking a sample 7-10 days before a sprayer moves through the crop gives time for the result to be seen and any minor 'top ups' can be made in the tank mix. At this time any micronutrient deficiencies can be identified.

Different crops have slightly different vital micronutrients. Manganese, iron, zinc, boron, copper and molybdenum are the most common with growing interest in the role of chlorine and iodine in plant health. A healthy level of organic matter in the soil and an active microbial population should supply most if not all of the crop's requirement. So treatments should not be made unless a test or visual deficiency has been identified – it's just a waste of money.

Legumes are particularly sensitive to micronutrients zinc, boron, and molybdenum, and cereals to copper, zinc and manganese.

A note on boron: plants produce sugar by day which they redistribute by night. B is essential for allowing the sugars to flow through the plant. Parts of a plant which are full of sugar are attractive to insects – this will not be a problem if the sugars are being redistributed efficiently at night. Wheat ears fill middle first, then top, then bottom – if there is any shrivelled grain check which part of the ear it occurs in to assess how deficient the plant is in B. I have often found cereals to be deficient in boron and treatments of liquid formulations at low doses following leaf tissue results have been successful. Boron still suffers from the '70's ADAS stigma that 'boron kills cereals' – that is true where soils have an extreme excess of the nutrient, but that does not mean we should be frightened to use it where it is required.

An extra benefit of copper above 2ppm and Boron above 1.5ppm will give good control of rust and fungus diseases. Good copper levels can eliminate take-all.

It is not sufficient simply to take a soil analysis result, see levels of an individual nutrient are high, and assume that nutrient is available to the crop. Different interactions by elements in the soil result in different nutrients being 'locked up' or available. This is why leaf or sap tests to back up soil results are necessary and where a holistic nutritionist is required. A FACTS qualified advisor simply has not been trained to understand how the elements interact and what effect this can have.

5. Fertilisers

I was unaware of some of the facts about the fertiliser products common to us in the UK. As a result I have changed the products I recommend and use on my farm and my clients' farms. I will concentrate on the big four: lime, phosphate, potash and nitrogen.

Lime: a low pH can cause problems with achieving vegetative growth, a high pH can cause problems with fruiting. It is vital to get pH right before tackling other fertiliser levels. Many farmers are unaware of the lime source they are purchasing. Different limes have extremely different neutralising values according to their parent product and their screen size. More details can be found in the table 3.

Speedy action is required and the presence of any other nutrient deficiencies should influence the product choice. We should also be addressing the calcium content of soils, not pH, as it is actually calcium we are trying to measure not hydrogen ions (which is what pH measures). On soils prone to waterlogging the difference in this detail can result in unnecessary action.

Phosphate: phosphate is most available on the day it is applied, so ordinary prilled products should only be applied when the crop is actively growing and requires it. Soft and hard rock phosphates are the exception as these are very slow release. TSP although commonly sold as the cheapest and highest concentration of phosphate should be used with extreme caution. This phosphate form combines with calcium very rapidly after application, rendering both elements unavailable to the crop. Due to this characteristic, TSP is unsuitable for building phosphate levels in the soil. It can however be used in small quantities as a starter fertiliser or for maintenance dressings – situations where it is purely feeding the plant. DAP and MAP are more stable forms as they are already combined with another nutrient – nitrogen. Of the two MAP would be the preference. Both MAP and DAP will prove more cost effective than TSP when efficiency is taken into account. P 'lock up' means it is too strongly bound to the clay colloid to be extracted by a plant.

Nitrogen: Urea is the TSP of the nitrogen world. Sold as being cheap and of high N concentration the losses associated with it can be huge; 25% can be lost in 3 days, 50% in 7 if the weather is hot and dry. Urea fits well if it can be either incorporated into the seedbed or applied just before or during rainfall. Urea also has a tendency to dry the soil out due to its concentrated salt base. Ammonium nitrate and liquid nitrogen each contain two types of nitrogen, one slow and one fast releasing. Liquid nitrogen is the product of choice – its liquid formulation gives it the best uptake efficiency. If all N could be applied for a crop in the 'zone of updraft' (area where the highest concentration of plant roots occur), 40% less total N for the crop would be needed. N leaching takes either Ca or Na with it. Nitrogen can be mixed with molasses or humic acid to help retain it in the soil. Legumes can extract 75-25% of their N from air and soil. The rest has to come from organic matter. If this is in short supply then it must come from an inorganic source.

Potash: K cannot be built on clay soils where pH>6.5 – there are not enough sites left on the colloids as they are occupied by H's. Knowing this could save farmers a lot of money. MOP is the least desirable K source – it tightens soil over time and is harmful to the soil microorganisms. Potassium Sulphate (K_2SO_4) is the product of choice.

We should aim to broadcast soil feeders such as lime, gypsum and manures. Elements with negative charge cannot be held by colloids and will leach. In these cases placing the 'plant feeders' – N, S and B - near the plant will give the most efficient return.

A note on sewage based products – all land treated with it will eventually reach the heavy metal maximum limits as heavy metals don't break down. The hormone content of these products is also of concern. These products do offer an opportunity to address organic matter content and can be useful to replace inorganic fertilisers in a form which is more available form.

Common UK Fertiliser Forms

Element	**Fertiliser**	**Nutrient Content**	**Form**	**Positive**	**Negative**
N	Urea	46-0-0		Good incorporated or immediately before rain	combines with Ca to lock up both
	Liquid Nitrogen	28/30/32 -0-0	mix or urea and AN	good uptake, 2 forms of N	
	AN	34.5-0-0		2 forms of N. Fast acting	
N & S	Ammonium Sulphate	21-0-0-24	(NH4)2SO4	Doesn't leach.	Quite slow release. Apply at least 4 months before harvest
P	TSP	0-46-0		Bad source	combines with Ca and both lock up. Plant feeder
	DAP	18-46-0		Not bad	
	MAP	11-52-0		Best source. Soil feeder	
	hard and soft rock phosphates			good slow release source over time	
K	MOP	0-0-60/62	KCL		Bad source. Damaging to microorganisms. Tightens soil over time
	Potassium Sulphate	0-0-50	K2SO4	very good source	
	Sul-Po-Mag	0-0-22-18Mg-22S		Excellent source	
Ca	Calcium Carbonate	25-35%	CaCO3	Best source	
	Dolomitic Lime		CaCO3, MgCO3	good to target mg and ca	avoid. Releases gaseous N on application
	Gypsum		CaSO4	good to target S and ca	not the best form of Ca
Mg	Epsom salts		MgSO4	Excellent source	
S	as above				

6. Organic Matter and Humus

I have mentioned several times now the importance of organic matter when growing crops. Organic matter has the structure of a sponge; it is a carbon based nutrient larder for plants infiltrated by a network of airspaces. Organic matter is a layer resilient to compaction and evaporation. Humus and organic matter should be the top layer in the soil profile. For an arable soil the target percentage for this layer would be 3-5%; however I have yet to test an arable soil in this range. My tests have been in the 0-2% range.

Humus is the uppermost layer of decomposing plant material. Once this material can no longer be distinguished it becomes known as organic matter. This upper soil layer benefits the soil in three ways: mechanically - making it easier to work, as a direct plant food, and by fundamentally modifying the soil bionomics, thus providing a hospitable environment for soil microbiology to exist and function. This layer can hold three times as many nutrients as clay. This layer is dark. Dark soils warm up faster which encourages crop growth earlier than light coloured soils which reflect heat. Humus also improves solar radiation utilisation, so makes more efficient use of the sun's rays for photosynthesis.

Organic matter decline is not just a UK or European problem - actually these regions suffer least on a world scale. The Missouri basin in mid west America has lost an average of 7 inches of top soil (containing the organic matter and humus) in 24 years. Australian organic matter is probably depleting faster than America's, but has only been under cultivation for one third of the time.

Soil Erosion at the Iguazu Falls

I visited the Iguazu Falls on the border of Argentina and Brazil (see photo on previous page). The river flows from Brazil through Argentina. The water at these falls used to run clear before the rainforests in Brazil were cleared for agriculture. It is now brown. This is soil erosion on a truly massive scale.

As we remove crop and crop debris we remove organic matter. Those who don't replace it with a bulky fertiliser or soil conditioner are depleting their reserves which will alter the texture of the soil. Weeds which thrive on badly drained soils or soils with a pan - in other words where the oxygen supply is deficient - will begin to take over and crops will struggle. This is part of the reason why grass weeds such as blackgrass are thriving in East Anglia today.

As I travelled I saw many examples of people trying to address this issue and rebalance their soils. The most popular method was to use free waste materials such as manures and horticultural waste to create a mixture of green and brown material, and turn it regularly in a heap to create high grade compost.

Another alternative I saw was green manures – crops established specifically to be turned in to increase organic matter.

I am trialling both methods on my farm. I also saw a lot of grass leys being used in rotations as these repair the soil during their 'life' by encouraging soil microbiology, establishing good root systems and, if grazed, cycling nutrients.

7. Composts and organic manures

To learn more about compost I attended the Soil Foodweb 4 day seminar in Oregon, USA. The course covered compost, compost tea, microbiology and microscopy as well as a day of farm visits. Many of the delegates on the course were practitioners of the methods described so it gave me a great chance to investigate how the theory taught on the course could be put into practice.

Compost is the process of taking brown carbon and green nitrogen based organic sources, mixing them together, waiting until the desired temperature is reached without the carbon dioxide levels being exceeded, turning the heap, then repeating the process until the heap no longer heats up. Performed correctly the process is aerobic, does not smell and kills off any weed seeds present in the original material.

I saw many different materials used as the base for the process. The key is to use what is available to you and then taking the time and effort to make a beneficial product - not simply spreading the 'compost' that may be available to you straight from a local green waste recycling site. Such sites do not attempt to get the green:brown (carbon:nitrogen) ratio correct for making a good compost. They are simply concerned with shredding and clearing surplus organic waste and plastic bags from any source! This process is giving compost a bad name in the UK. The drawbacks to composting on farm in the UK are sourcing the right starter materials and finding the machinery to turn the compost during production. I do not believe these are insurmountable, however, as for smallish projects a loader or forklift can be used and there is a huge variety of materials which could form the base. For a methodology for making good compost see Appendix 1.

The compost tea method takes a sample of good compost and uses it as a teabag in a tank of constantly aerated water to gently bump all the microbiology off the organic material and into suspension in the water. After about 24 hours of aeration the resulting liquid can be used to inject soil microbiology into soils or sprayed directly onto plants as an organic fungicide. The constraints of this process on a commercial arable scale are the lack of shelf life of the product, the wide filter mesh required for application and the volume of the product.

Both on the course and later on my wider travels I saw many compost and compost tea sites, methodologies, products, trials and processors. Each was slightly different and I want to discuss three in greater detail.

The first was on a farm on a peninsula near Adelaide with salt pans creeping up all around it. Compost has helped stave off this unwelcome mineral. The farmer heaps up the solid dairy manure, runs a hose pipe as and when required across the top to dribble dairy slurry onto the heap to keep it moist, and leaves it to rot down for a year – no turning. The end product was pretty good and certainly doing a good job in increasing organic matter and soil microbiology. This seemed a practical solution when time to turn the product is the constraint and the raw material is plentiful.

The second farmer had become so focused on making compost he had started growing and harvesting the base materials specifically to make the best compost, which was being returned to the same land on which the base materials were being grown. To me this seemed to be missing the point a little but was a good reminder not to lose sight of the end goal, and highlighted the need to make a compromise between creating the best possible product and using the materials available to you.

The third farmer made me think about my brilliant new idea - to go home and make tonnes of compost - and question it. Why collect bulky materials in a central point, mix them, turn them again and again and again, then load them back up, spread them back on the fields and incorporate them? Why not grow something in the field which can be incorporated to bring the same benefits without all the work and cost of carting and turning – particularly if the base material is not readily available to you?

This farmer is John Ikerd from central Queensland, Australia. John set out to have less lorries coming into his farm delivering purchases and more lorries leaving his farm with output. John is situated in an intensive arable area of Australia. He began fencing all his paddocks and establishing a pasture mix containing grasses, broad leaved species and legumes (see picture below). John leaves this mix until it has shed its seed then strip grazes cattle over it, followed by self shearing sheep. The action of the animals' feet treads the seeds in and the pasture continually reseeds itself. The animals recycling the nutrients and the legumes in the seed mix are sufficient to fertilise the pasture. This seemed to me a pretty perfectly balanced system.

I have not gone home and begun fencing! However this is a model we should all strive to emulate for our own businesses in our own ways. I am currently trialling green manures and making a high grade compost on my home farm – home made compost, made from cattle manure and green waste site materials and

Me standing in John Ikerd's pasture just prior to grazing

green manures - on land destined for spring cropping. I have recently travelled to France to investigate green manures and cover crops such as buckwheat and mustard and the added bonuses they may have on grass weed control.

8. Soil structure

With no good soil husbandry information readily available to farmers the art of working the soil is being lost and many farmers' sympathy for the process along with it. It is becoming increasingly common to see tractors with high horse power trying to cover more acres – the result, soils being worked when they are too wet, which is made possible because of the high horse power available.

We are forgetting the basic aims of soil cultivation in favour of doing as little as possible to create a fine crumb on the top two inches alone, irrespective of what is going on further down the soil profile. The aim of primary cultivation is to till crop residue into the aerobic root zone in order to break it down to be recycled and to repair soil structure to facilitate better air and water movement through the soil.

Soil left in ridges will warm up faster, dry out faster and be ready to work sooner than worked soil left flat. It is then imperative that further cultivation to plant the seed or improve tilth does not damage the lower structure, so tractors and machinery should get lighter as seed establishment progresses and tyres should become wider. Care must also be taken to carry out primary cultivations when the soil is quite dry to prevent smearing. Secondary cultivations - drilling and rolling – should take place when the soil is damp as any dust behind a tractor is made up of clay colloid and the nutrients attached.

An ideal soil will have 45% minerals, 5% humus, 25% air, 25% oxygen. This creates a well drained, oxygenated soil that allows roots and soil microbiology to respire, cycle nutrients and grow.

Soil is negatively charged. Particles should repel each other – as magnets. Under adequate mineral balance they do and thus are resilient to machinery running on them, thus maintaining air and water spaces – much like a sponge. So the better condition the soil is in the more abuse from machinery it can take without creating compacted layers that require mechanical correction.

The four cornerstones of soil management in order of importance are:

- Soil aeration
- soil water
- residue decay
- soil fertility

Soil aeration is vital because a sealed soil surface will prevent oxygen entering and prevent carbon dioxide from leaving. Anaerobic conditions will be created and photosynthesis will cease. Low oxygen soil struggles to use N, S, K and Mg. Anaerobic bacteria cause denitrification and increase N losses. Anaerobic conditions are also favourable to many weed species and unfavourable to most crop species.

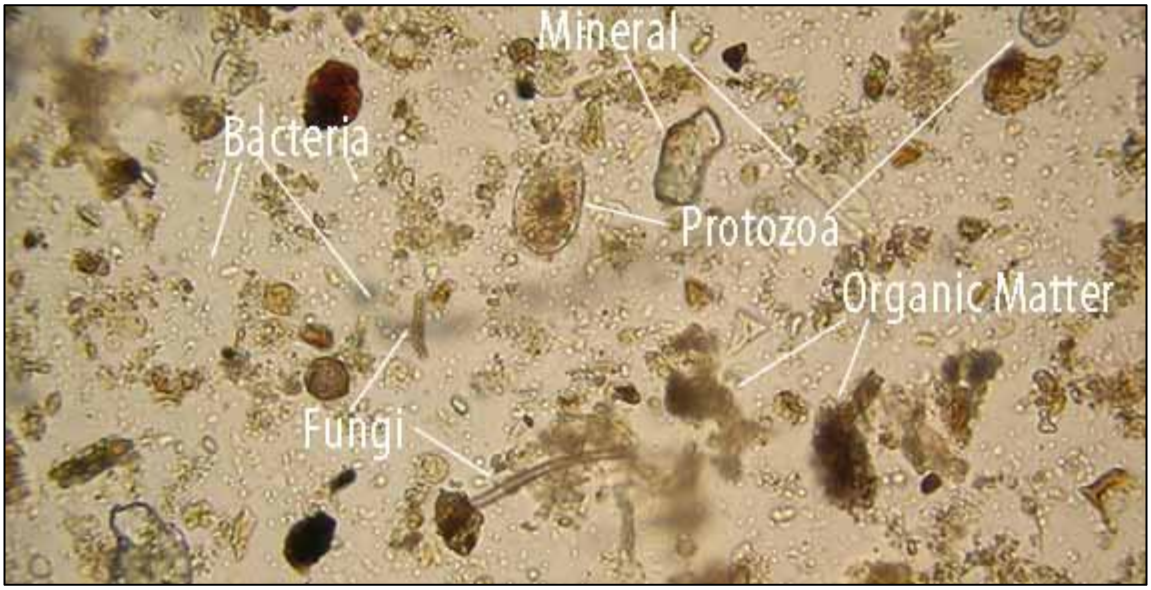
One way anaerobic conditions are created is through waterlogging, either because of a high water table or through compaction. Thus soil water movement is important. A soil with 1% organic matter can hold 10,000 gallons of water, (1 inch of rain equals 28,000 gallons). This organic matter is just as important in retaining moisture as in allowing good penetration.

Residue decay creates humus. Humus will not allow fertiliser acids to drive out held nitrogen, which is how leaching occurs. Humus only permits root exudate acids to pull held nitrogen, unlike clay which creates a more efficient use of nitrogen. Humus is lost by working wet ground.

The final cornerstone is soil fertility. Roots release H ions which trade places with cations - positively charged nutrients held on clay colloids so the plant can take them up. Roots struggle to penetrate soil at 300 lbs pressure so wheel tracks are not generally penetrated by roots. Therefore any chemical or fertiliser applied in the tramlines will be wasted.

Nutrient deficiencies on clay soils will take more fertiliser to correct but will hold onto it for longer. As clay soils are made up of fine particles there are obviously more of them and so have a larger surface area on which to hold nutrients. Sandy soils will struggle to hold on to nutrients because of their lack of charge and large particle size which means a small surface area for nutrients to bind to. Sands should be ‘topped up’ little and often.

9. Soil microbiology



A soil sample under a microscope

John Ikerd's system is heavily reliant on the soil microbiology – bacteria, fungi, protozoa (see photo above) and nematodes breaking the manures and crop residue down to release the nutrients they contain in a form the plant can take them up. Microbiology is the key to nutrient release from the soil and decomposition of crop debris. Think of the food chain; soil microbiology is there at the bottom, supporting the rest of us as we balance on top of it.

I would like to introduce you to the 'Theory of Succession' as presented to me by the Soil Foodweb. Bare rock or sandy beach is first colonised by bacteria, the smallest of the microbes which begin to break down organic debris which then begins to form humus. From a single spore fungi begin to colonise. Their hyphal action helps aerate the humus and create structure. Seeds blown or dropped into this medium begin to grow and the roots help mix the humus and top layers of soil. The plant roots wear away the bedrock, chipping bits off which become part of this 'recipe'.

Over thousands of years and repetitions of this cycle the soil becomes richer and bigger soil microbes and insects colonise - such as earthworms - responsible for mixing new organic debris into the subsoil for microbes buried deeper to work on. The species diversity and size the new soil can accommodate grows with the depth of soil and the increase in nutrient value, starting with the lower grasses (e.g. blackgrass and bromes) through - as the soil biota increases - to higher grasses (e.g. wheat and barley) then on to small broad leaved plants (e.g. oilseed rape) to large broad leaved plants (e.g. hedge plants) and eventually to saplings and finally to mature trees. The ratio of bacteria to fungi shifts throughout this process from mainly bacteria initially to mainly fungal by the mature forest stage. Left to its own devices soil will always try to grow to forest. We know how rich and fertile forest floor soil is; it is only our intervention that prevents afforestation all over the place. This is not to suggest we should allow forest to become part of our rotation, but encouraging the correct bacteria:fungi ratio for the crops you are trying to grow will make life a lot easier.

We must analyse our soils for bacteria and fungi to understand what sort of environment we are encouraging. I have surveyed a number of soils and organic fertilisers in the last year. The soil from the Cambridgeshire field with bad resistant blackgrass had no sign of fungi, good nematodes or protozoa and virtually no bacteria. The best soils that are easy working, that see no signs of crop nutrition deficiency and where weeds are easily controlled, have fungal presence and plenty of bacteria, a few protozoa and even the odd good nematode. We could and must do much better.

As with all living things, microbes need water and air, and will struggle to survive in anaerobic conditions such as water logging or compact layers. A good aerobic zone is therefore critical - 70% of microbial activity occurs in the top two inches, the rest in the next 5 inches. Any lower than this is the anaerobic zone, where residue will not break down due to lack of microbes. When cultivating, if previous years' residue is pulled up it is either a sign of it being incorporated too deep, or an absence of microbes.

A quick sniff test is a good indicator of the presence/abundance of microbiology. Soil will not smell at all if microbiology is absent. Soil will smell bad if only 'bad' bacteria – anaerobic ones - are present. Soil will smell good and increasingly better if good microbiology is present and active. It can be difficult to encourage microbes on some soil types. Fungi grow better in acidic soils, bacteria in alkaline soils. Another indicator of soil health are the earthworms. Twenty five earthworms/ft^3 indicates good soil health – some soils will never be hospitable to worms.

Good bacteria can have other benefits: mycolytic bacteria dissolve mycelium of fusarium graminae/culmorum and sclerotinia. Good species of fungi can also digest take-all.

You cannot simply change one aspect of the physical, chemical or biological property of a soil and expect that change to last. Alter in isolation and it will revert. All three elements have to be in balance. For instance: add a microbe supplement alone and it will mine the soil and die out. Subsoil alone and it will eventually collapse. Add inorganic fertiliser alone, it will be used up or disappear.

First decide what has caused the problem. For instance on my farm I have blackgrass on a very high calcium chalk soil. I spray the field with herbicides and the blackgrass comes back next year. The cause of the problem is the very fine chalk particles packing closely together, eliminating oxygen to the root zone. Blackgrass thrives in anaerobic conditions and my crops do not. The solution is to add organic matter in the form of compost and green manures to hold the soil structure open, to physically change the soil so that the soil microbes can get to work to mineralise more nutrients and move the soil through a phase of succession.

10. Good soil husbandry - methodology

Plants like humans are fussy eaters and prefer to take their nutrition from organic sources where possible. This is a lot more efficient as the plant can draw from soil reserves as and when it requires. Thus the secret to good crop nutrition is to feed the soil and try to make as many of the required nutrients available from the soils as possible. This means a multi pronged attack:

1. Have your soil sampled and mapped to know what's there.

2. Carry out leaf tissue analysis throughout the growing season to assess what the crop is struggling to extract from the soil and what is available (a nutrient's mere presence in the soil does not necessarily mean the plant can get hold of it).

3. Increase soil organic matter levels to increase carbon, oxygen, hydrogen and water availability and increase cation exchange to increase the potential of the soil to hold nutrients. This by default will make the soil more workable. Do not remove crop residues unless you are replacing them with another form of bulky organic manure.

4. Where macronutrients have to be added artificially ensure 'soil building' fertilisers are used such as DAP/MAP - not crop feeders such as TSP – it will take 5 times as much fertiliser to build indices this way if you ever achieve it at all! Consult an expert as to whether it is possible to build the nutrients you require on your pH (calcium content) soil. For example you will struggle to build K indices on soils with high pH (calcium content). Trying to do so will simply waste money. In such situations foliar feeds are the most cost effective option.

5. Many micronutrients can be made available from organic sources. Recurring problems can be dealt with as a result of plant analysis and be corrected by foliar means.

6. Cultivate your soil as little as possible whilst maximising water and air movement through the soil - remember this is the most critical point, more so than what the seedbed on top looks like. A crop with good rooting potential will be more competitive to weeds and will need to rely less on residual herbicides, making seedbed quality less important than below surface structure.

11. More questions than answers

Having been enlightened by my world tour and reading quest I began putting some things into practice on my own farm. When I applied for my Nuffield Scholarship I had begun soil sampling and GPS mapping and spreading our P, K, Mg and pH. The farms are still in the process of being mapped, and the cost savings in base fertiliser paid for the GPS hardware in the first year. Current use has demonstrated a 25-50% saving in the amount of base fertiliser used on the farms compared to flat rate application. I also stopped trying to use K base fertiliser to build K indices - I now know I never will on our calcareous soils. Leaf tissue analysis proved this method was not creating available potassium, it was simply being locked up and was a waste of money. I now use a foliar feed potassium and sulphur mix which has had great farm trial results on our soil types.

My use of leaf tissue analysis on both my own farms and my customers' has greatly improved my knowledge of soil and plant interactions and my findings regularly confirm the literature I scoured. For instance this year's results highlight exactly the farmers who use sulphur fertiliser on their wheats, as not only is the sulphur level in the plants higher but, far more markedly, the potassium level is sufficient in these samples where the sulphur has bound to the free calcium (which is plentiful in our local soils) and allowed the potassium to become available to the plant.

The second big change for us at home has been the move away from routinely using manganese at 2l/ha several times a year – for no real reason - to using magnesium in its place which our leaf tissue tests always show deficient.

Finally I have hired an N Sensor with fantastic results from our first season's use. Using the 'absolute' programme we have found that with both starter fertiliser use in the autumn and liquid fertiliser in the spring it is possible to cut nitrogen fertiliser use by half compared to the standard RB209 approach.

Structurally I have been trying to take more time to assess soil conditions prior to cultivating by pulling up oilseed rape plants to see where they hit a pan, or not. I have also been using a penetrometer and digging samples from every field to assess harvest damage and pan presence/depth. I am also trialling homemade compost and green manures as discussed earlier.

With regard to our soil microbiology, I have taken more time to sniff soil: when being cultivated, when I have pulled up roots, or been soil sampling. I have also been examining samples under a microscope to see what life may be present versus samples I looked at on the course in Oregon – the results have not been very encouraging. There is however a definite spread with some farmers faring better than others, meaning we could all do better. My experiments with compost and green manures will hopefully encourage my microbiology. I would also like to trial adding a feed source such as molasses to my glyphosate and liquid nitrogen to soften their effect on the soil microbiology and improve their uptake by the plants.

12. Conclusions

1. In the UK we search for a one-size-fits-all system such as the RB209. To be most efficient with our fertiliser use we simply cannot force such a system. We need to accept this, to accept that we need specialists and ensure they are trained thoroughly to carry out what is a field, farm and crop specific job.

2. All farmers need to take ownership of their soils and the expenditure on them – not to simply moan as fertiliser prices rise but to be smart about it and find more efficient ways of sourcing and applying the products really required. Don't just calculate these requirements on paper, or from theory, from RB209 or historical guestimates.

3. The more organic matter that can be built in arable soils, the more water can be held in the land which would ease the urban flooding caused as more of our country is covered in concrete.

4. Rothamstead believes removing straw as often as once every three years does not have a negative effect on soil organic matter. Farmers should not be removing it any more frequently than that unless they are replacing it with another bulky source such as FYM or compost.

5. The current FACTS qualification is insufficient to offer any nutritional advice beyond how to use the RB209 manual and does not convey any practical or holistic nutritional advice or detail on the quality of fertilisers as plant foods etc.

6. The art of soil husbandry is being lost in favour of using more horse power to work soils in situations that will only create anaerobic conditions. These are unfavourable to the soil microbiology and roots trying to grow, but favourable to injurious soil microbiology and weed plants.

13. Recommendations

1. Soil courses delivered as part of an agricultural qualification in universities and colleges need reviewing to include a more holistic approach. These courses should also form a greater part of the syllabus including practical soil sampling and digging, greater discussion on the mechanics of soil, when and how to work it and what the goals are when a cultivator leaves the yard.

2. The theory of nutrients as soil entities and plant foods needs studying in institutions along with how they interact and the benefits and drawbacks of the sources with which they can be delivered by farmers. Finally on this point, soil microbiology needs teaching, what to look for under a microscope, what the benefits of healthy soil microbiology are and how they can be damaged or encouraged.

3. Thorough soil sampling should be carried out as a matter of course before any fertiliser is applied. Tissue testing should be carried out before any spray applications are made to allow the spray contents to include liquid nutrients to correct any deficiencies seen in the tissue test results.

4. Encouragements to farmers to build OM by adding bulky materials to the land or retaining straw rather than baling it and to apply a balanced nutritional programme rather than just applying tonnes of inorganic nitrogen to the land, could come from cross compliance or agri-environment schemes.

5. The advisor's 'FACTS' qualification needs to be reviewed and improved. It may be more practical to introduce a higher level qualification to encourage real expertise in the subject plus a more tailored approach which needs proper remuneration on farm for the time and expertise involved in fitting exactly the right products into the right situations on the right soil types at the least cost and for the most economic return.

6. Farmers need to stop baling straw simply to burn it.

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Bibliography

Andersen, Dr. Arden. Science in Agriculture: Advanced Methods for Sustainable Farming. Acres USA. 2000.

Balfour, Lady Eve. The Living Soil. 2nd Ed. Soil Association. 2006.

Kinsey, Neal. Hands on Agronomy. Acres USA. 1993-95.

Lewis, Wayne. & Lowenfels, Jeff. Teaming with Microbes: A Gardeners Guide to the Soil Foodweb. Timber Press Inc. 2010.

Savory, Allan. Holistic Management: A New Framework For Decision Making. Island Press. 1998.

Scamell, Jo. A Practical Investigation into the Vitamin and Mineral Nutrition of High Yielding Dairy Cows. Nuffield. 2000.

Schriefer, Donald. From the Soil Up. Acres USA. 2000.

Walters, Charles. Albrecht, Dr. William. Albrecht Papers (volumes 1-4). Acres USA. 3rd Print. 1996, 1975.

Walters, Charles. Weeds - Control Without Poisons. Acres USA. 1996.

Weber, Karl. Food, Inc. Public Affairs. 2009.

Wheeler, Dr. Philip & Ward, Ronald. The Non Toxic Farming Handbook. Acres USA. 1998.

White, Robert. Principles and Practices of Soil Science: The Soil as a Natural Resource. 4th Ed. Blackwell Publishing. 2006.

Wibberley, Professor John. A Brief History of Agriculture in the UK. RuSource. Jan 28. 1998.

Zimmer, Gary. The Biological Farmer. Acres USA. 2000.

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Appendix 1. Compost from the Indore method

The materials needed are animal and mixed vegetable wastes, a base for reducing acidity, air and water.

The vegetable waste may include all vegetable and crop residues to be found on the farm or in the garden, such as weeds, leaves, grass, tree and bush prunings, hedge and bank trimmings, straw and chaff and dust bin refuse. If the proportion of fresh green material is likely to exceed 30% any excess must be withered before composting begins, otherwise there is a danger that silage rather than humus will result. It is also important that the vegetable wastes should be well mixed, and where these are long it is helpful to cut them. Any available animal manure may be used.

As a base, earth, wood ash, chalk, sea sand, or a mixture of some of these substances should be used. Calcium carbonate is preferred which will neutralise excessive acidity and at the same time provide suitable conditions for nitrogen fixation.

The heap should be made 10 feet wide, up to any total length but it should be made in 5ft sections. Each section should be built up to a height of between 4 and 5ft. The mass should sink to 3ft after settling. Failure to do so is an indication that insufficient air has made its way into the heap. Each section should have two vertical air vents which can be made by placing 2 x 6ft fence posts in position before the section is made and then removed after construction.

The sections are built in layers: first mixed vegetable waste 6inches thick, then a 2 inch layer of animal manure topped with a sprinkling of base and repeated. If the material is dry the layers must be watered as they are made.

After three weeks the heap should be turned from one end. As each section is remade the airvents should also be remade and the layers watered again if necessary. At no time should the heap be dry (possibly cover loosely with black plastic). At the end of three further weeks the heap is turned again but without airvents this time.