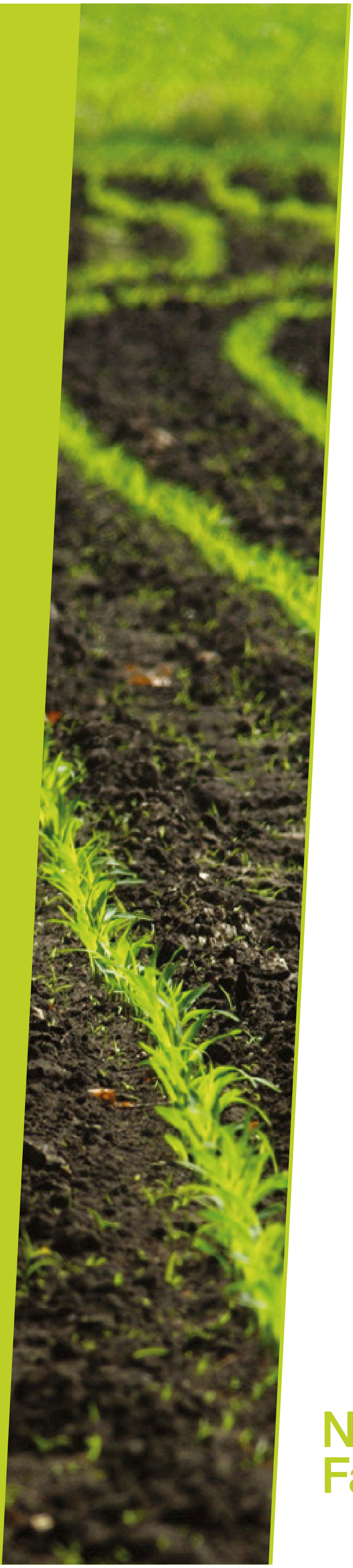

NTS
Nutri-Tech Solutions®

Soil Therapy™

General Guidelines and Operating Principles

Nutrition Farming®

Contents

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General Guidelines & Operating Principles

A fertiliser should increase fertility, otherwise it does not deserve the name. Any product that damages the soil is a defertiliser. There are some products that have the capacity to fall into either category, and that capacity is defined by the way these products are used. Application rates and times, suitability for different soil types and crops, and consideration of overall balance are some of the factors involved in determining the relative value of any input in a program. Our analysis should provide valuable guidelines to any grower concerned with improving soil and plant nutrition, raising the quality of produce and increasing production in a sustainable fashion.

1. The Defertilisers

There are some products that have no saving graces. They are damaging in any context and should be avoided where possible. These products include:

1.1. Anhydrous Ammonia – This product was used to create rock-hard landing strips in Asian jungles during the war. It is a soil destroyer without peer. Low cost N is the attraction, but how do you define cost? At what cost do you give your soil a “use-by” date?

1.2. Muriate of Potash – This potash source includes 50% chloride. Standard applications of Muriate of Potash can produce higher concentrations of chlorine than is required to kill all of the unwanted bacteria in a swimming pool. The bacteria and other microbes in our soil are our most valuable asset. Why subject them to indiscriminate slaughter? Sulfate of Potash may be 20% more expensive, but it is a far more valuable product, and the sulfate content is almost always needed in the soils we analyse.

1.3. Triple Super Phosphate – All of the acid-treated phosphates share the same weakness (i.e., they can “lock up” and become unavailable), but Triple Super is a monster. This concentrate has a pH-level of 4.4, and such a low pH amplifies the “locking up” process. Extensive research using radioactive tagging has revealed that, depending on weather conditions, the phosphate in Triple Super is largely unavailable within 30 to 70 days. The negatively charged phosphate bonds with positively charged calcium, forming tri-calcium phosphate, an unavailable form of both phosphate and calcium. MAP and DAP with pH-levels in the 6.5 range are more stable and cost-effective, but they, too, will tie up with calcium within 90 days.

The DAP treated plant on the right has lost its protective fuzz and it has also lost the capacity to retain soil in the root zone.

1.4. A real fertiliser by comparison – NTS Soft Rock™, our colloidal phosphate, can never lock up and will provide ongoing phosphate availability for up to 6 years from a 300 kg per acre application. It is advisable to plan ahead with applications, allowing for the 8 to 10 weeks required for NTS Soft Rock™ to kick in. If this time frame is not possible, then a little starter phosphate like MAP is required until NTS Soft Rock™ becomes available.

Explaining the Analysis

We can provide more insight into our approach by explaining the logic and philosophy behind each recommendation.

2. Base Saturation – The Key To Balance

Base saturation percentages basically reveal the productivity of a soil. The cations – **calcium, magnesium, potassium** and **sodium** – must be in balance to ensure conditions are perfect for the availability of all other elements. If a balance can be achieved, then your soil will really perform (the other elements must, of course, be present in sufficient quantity to be made available).

Soil type determines the appropriate percentages of **calcium** and **magnesium**. A heavy clay soil requires 70 – 75% calcium and 10% magnesium. Magnesium is the element that holds a soil together, and excess levels in clay conditions produce a tight, closed soil with poor aeration and drainage.

Conversely, in a sandy soil, the problem is too much air and poor water retention. In this situation we increase the magnesium base saturation to 20% to close up the soil.

The **potassium** base saturation should not exceed 5%, with the exception of table grapes and woody plants, which require 7%. **Weed problems** can be directly related to potassium levels exceeding 7.5%. Many soil test recommendations continue to suggest potassium regardless of base saturation balance, and many problems are associated with this misunderstanding of the importance of cation balance.

Weed problems can be directly related to potassium levels exceeding 7.5%

2.1. Sodium base saturation levels should not exceed 1.5%, but the most critical consideration is that sodium levels should never exceed potassium levels. In this situation, the plant will uptake sodium instead of potassium. The problem will not become obvious until hot weather conditions, when the sodium can expand, bursting the cell walls and causing considerable plant damage.

2.2. The cation **aluminium** only becomes available in low-pH situations, and an excess of this element on a base saturation table suggests a major calcium deficiency.

2.3. **Hydrogen** becomes excessive when there are insufficient available cations to fill the colloid. It will be displaced as soon as the cation deficits are addressed.

3. CEC – Cation Exchange Capacity

CEC, Cation Exchange Capacity, is essentially a measure of the storage capacity of a soil. The level of both moisture retention and nutrient retention is governed by the CEC.

A light, sandy soil will have a CEC of less than 5, while a clay soil might have a CEC exceeding 30. The CEC can be viewed as equivalent to a car parking area.

In a low-CEC sandy soil, the colloid has very few free spaces, so fertilisers and water just drive on through. In a high-CEC soil, there are many more free spaces and parking is no problem. There are only two ways to increase the CEC or storage capacity:

(1) Increasing calcium levels which can increase the CEC by one or two points in very light soils.

(2) The main technique to increase the CEC is by **increasing organic carbon levels**. Nutri-Store 180® has a CEC of 180 and, in this context, can provide exceptional response in terms of improving nutrient and moisture-holding capacity.

4. pH-Level

pH is a measure of active acidity or alkalinity. A pH-level of 7 is neutral. Values higher are **alkaline**, while lower values are **acidic**. Calcium is generally regarded as the governor of soil pH but, in actual fact, magnesium can have more impact on pH-levels. The other cations – potassium and sodium – can also have an influence. It is never safe to assume that a neutral or high pH-level guarantees adequate calcium, because this is often not the case.

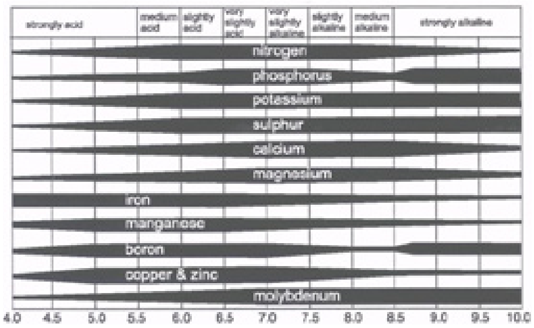


Figure 1: Nutrient Availability according to pH.

An essential principle of the **Soil Therapy™** approach is the fact that pH-levels become self-adjusting when calcium, magnesium, potassium and sodium are in proper equilibrium. The concept of determined liming requirements, based on pH-levels, without consideration of the importance of cation balance, is severely flawed, and many stupid mistakes are a result of this approach.

It is always preferable for the pH-level to be on the acidic side, as the breakdown and release of mineral elements is facilitated more rapidly in slightly acidic conditions. A pH-level of 6.3 to 6.8 is regarded as ideal.

The more the pH-level varies, above or below this ideal, the more problems are encountered. Many soil microbes cannot exist in very low or very high pH conditions, and pH extremes also cause "lock-ups" of trace elements. Several heavy metals only become available in very low pH soils.

4.1. Low pH-Level Problems

4.1.1. Aluminium and **iron** solubility increases as soil pH lowers. This can create toxicity problems. Excess aluminium and iron can also combine with phosphorus, forming complex compounds that are not plant-available. Broadcast phosphorus will quickly become unavailable (with the exception of colloidal phosphate).

4.1.2. Low pH can also release excessive amounts of **manganese**, **copper** and **boron** which can, on some occasions, become toxic.

4.1.3. Earthworms cannot tolerate low pH-levels.

4.1.4. Nitrogen-fixing bacteria and sulfur-oxidising organisms are also adversely affected by low pH.

4.2. High pH-Level Problems

4.2.1. Iron will become up to 90% unavailable in soils over pH 8.0. Any iron deficiency will be magnified in high pH soils.

4.2.2. If **high calcium** is the root of the high pH-levels, then magnesium, potassium, boron, zinc and copper can become "tied up".

4.2.3. A high pH-level is unsuitable for many microbe species. Most of the **predator fungi,** which are essential for protection from fungal disease, cannot survive in high pH soils.

Most of the predator fungi, which are essential for protection from fungal disease, cannot surivve in high pH soils (rust fungus).

5. The Calcium/Magnesium Ratio

This is the single most important fertility ratio and should be around 5:1 (in terms of base saturation) in favour of calcium in light soils and at least 7:1 in heavier soils. Low calcium:magnesium ratios are usually indicators of serious problems. These include compacted soil, bacteria that can't proliferate and weed take-over. An appropriate calcium:magnesium ratio will be an obvious consequence of the successful achievement of cation balance.

6. Conductivity (EC)

The electrical conductivity measurement is often used to gauge the amount of soluble salts in a soil. The conductivity of soil increases with an increase in soluble salts.

7. Organic Matter (OM)

Organic matter is the essence of fertility. It is the lifeblood of the living soil. When a soil has become lifeless and non-productive, it will invariably be related to low levels of organic matter. Organic matter is a reservoir of plant-available nutrients and moisture, but it is far more than that. It is the structure within which billions of teeming soil microbes make their home. Organic matter levels determine the size of the microbe workforce in any particular soil. Organic matter levels must be maintained at **more than 4%** to ensure a healthy workforce.

When levels fall to between **1.7% and 3.5%** organic matter, that volunteer army is reduced and placed on limited rations. When organic matter falls **below 1.7%**, there is no army. The living soil has died and opportunistic pathogens can create havoc. In this situation, crops are literally grown hydroponically and the lifeless soil becomes a medium to stand the plants in. The nutritional value of crops grown in these conditions is poor, and both livestock and humans further up the food chain will suffer accordingly. Many laboratories test **organic carbon** instead of **organic matter**. The two values have a direct relationship, as the organic matter can be obtained from multiplying organic carbon by 1.7.

Rust fungus through a microscope.

7.1. A Carbon-Centred Approach

Organic carbon is a major focus in all of our fertility programs, as it is simply not possible to build high-production fertility without consideration of this element. We have developed a unique carbon-centred product range, which is designed to either increase production of organic carbon, or to provide a direct injection of organic carbon whenever necessary.

7.2. The Carbon Solutions

7.2.1. NUTRI-STORE 180®: Nutri-Store 180® is a world-first. This product represents a major breakthrough with enormous potential in agriculture. The patented manufacturing process of Nutri-Store 180® involves the composting of high-carbon, bituminous coal – a process never before achieved. The inert carbon is converted to precious organic carbon by this composting process. Soft rock phosphate, cow manure, fish protein, molasses and a special vitamin/mineral blend are composted in conjunction with the coal to produce a high performance, humus-based, organic fertiliser. Applications vary from **500 kg to 2 tonnes per hectare**. Aside from the impressive fertilising capacity of Nutri-Store 180®, some of the other benefits include: improved nutrient and moisture retention, soil detoxification, increased organic carbon conversion, improved soil structure, a buffering capacity against both sodium and pH fluctuations, marked increases in microbial activity and associated disease protection.

7.2.2. NTS LIQUID HUMUS™: This humic acid is a source of root-zone organic carbon and a remarkable microbe stimulant. It is also a **natural chelating agent** that can be used to chelate (increase the plant-availability) of all elements.

7.2.3. DIY LIQUID HUMIC ACID RECIPE:

You can mix up your own humic acid to supply a cheaper source.

To produce a 6% potassium humate liquid:

- Add 1 kg of NTS Soluble Humate Granules™ very slowly to 10 L of water, under vigorous agitation.
- 10 – 15% of the humates are insoluble; let sit overnight and then siphon the soluble fraction from the top (avoiding insoluble sediment resting on the bottom). The insoluble sludge remaining is a valuable addition to composts.
- DIY Liquid Humic Acid can also be applied at 30 L/ha with 10 – 30 kg/ha dissolved urea, (or UAN), whenever a Nitrogen boost is required.

Note: Humic acid is not compatible with acidic inputs, such as soluble sulfate, phosphate or nitrate, or agricultural chemicals including herbicides, insecticides and fungicides.

7.2.4. NUTRI-MATE ORGANIC HUMATES™: A high-carbon, slow-release humate product containing 68% carbon and up to 75% humic acid. Humates are widely recognised as incomparable soil conditioners.

7.2.5. NUTRI-SEA LIQUID FISH™ and MOLASSES: Both are valuable carbon sources, and they work particularly well together. Nutri-Sea Liquid Fish™ is also an excellent fertiliser, trace element source, soil conditioner and microbe stimulant. The microbe-stimulating capacity ensures effective organic carbon conversion during the breakdown of organic matter.

8. The Soil Therapy™ Approach To Nitrogen (N)

There are several critical factors to consider with the use of **nitrogen**. This element can be a potent energy source, or it can be a major source of destruction. It can be an invaluable tool for high production fertility, but it is misused and abused too often. Hopefully the following section will provide valuable guidelines for the effective, sustainable use of nitrogen.

8.1. The Carbon/Nitrogen Problem

Nitrogen can be at its most destructive with regards to organic carbon depletion. The essence of the relationship between these two elements is as follows: soil microbes love nitrogen. In fact, the presence of excess nitrogen generates a feeding frenzy amongst the billions. It is part of a natural cycle that nitrogen becomes an entree for a carbon feast. The microbes must have carbon after nitrogen. If a carbon source is not available, then the microbes will turn to the precious reserves of organic carbon. This is the major reason for the serious depletion of organic carbon during the last few decades.

8.2. The Carbon/Nitrogen Solution

This soil mining scenario can be avoided by adopting the following three-step approach to nitrogen usage:

8.2.1. Always determine appropriate nitrogen usage by soil test data. “More is never better”. Only use what is necessary.

8.2.2. Split nitrogen applications whenever possible. Large applications at pre-plant are often wasteful and destructive, because seedlings do not require this amount of nitrogen. Many irrigators are adopting a policy of daily nitrogen application, often involving only 2 – 3 kg per hectare each day.

8.2.3. Finally, and most importantly: **Always provide a suitable carbon source with every nitrogen application.** Ideal sources include: Nutri-Sea Liquid Fish™, molasses and/or NTS Liquid Humus™. NTS Liquid Humus™ will hold nitrogen in the root zone and prevent leaching, thereby dramatically increasing the effectiveness of all nitrogen sources.

8.3. The Nitrogen/Magnesium Problem

Nitrogen drives out calcium. Nitrogen is the most leachable of all elements. When nitrogen leaches, it takes a passenger, and that passenger is invariably calcium. Calcium and magnesium levels are directly related. The removal of 10% of calcium involves a corresponding 10% increase in magnesium. This is how nitrogen can effect soil structure. Reducing calcium and increasing magnesium will tighten a soil, reducing aeration, microbial action and fertility accordingly.

The problem is compounded by a specific feature of the relationship between nitrogen and magnesium. Excess magnesium will combine with nitrogen, forming a magnesium nitrate salt that will dehydrate and reduce the effectiveness of nitrogen. We now have a situation where extra nitrogen is required to do the same job. For this reason, soils with a high magnesium base saturation require up to 50% more nitrogen.

Growers are rarely advised of the mechanics of this vicious cycle, due to a combination of ignorance and the vested interests involved in extra nitrogen sales.

8.4. The Nitrogen/Magnesium Solution

8.4.1. Soil pH should never be used as a guide to calcium requirements. **Base saturation** is the appropriate guideline. Magnesium has more impact on pH than calcium, so reducing calcium and increasing magnesium through excessive nitrogen usage will raise soil pH. Liming requirements based on pH-levels are irrelevant in this context (calcium can still be deficient, no matter how alkaline the soil).

8.4.2. A good **calcium/magnesium ratio** is vitally important to improve soil structure, reduce nitrogen requirements and increase yields.

8.4.3. The **nitrogen source** is critical to avoid the vicious cycle described above. **Ammonium sulfate** is usually the best nitrogen source in this context. This product is far more stable than urea. It leaches less, reducing the amount of calcium removed, and, most significantly, the sulfate component can be used effectively as a technique to remove excess magnesium. As the sulfate breaks its bond with ammonia, it can team up with excess magnesium, forming magnesium sulfate (epsom salts). Epsom salts can be easily washed out of the soil with irrigation and rainfall. Finally, the acidifying effect of ammonium sulfate can be beneficial in high magnesium/high pH soils.

9. Phosphorus (P)

Our "ideal levels" for phosphorus are higher than those recommended by the majority of analysts, reflecting our focus on the critical importance of phosphorus in the fertility equation. Phosphorus is the governor of plant brix levels (a measure of the sugar and mineral content of the plant). 70 ppm or more will always produce good quality crops, presuming there are no other limiting factors. The key is to have **at least 70 ppm of available phosphorus** throughout the growing season (i.e., according to the Albrecht level of P). The only product capable of achieving this is colloidal phosphate, or **soft rock phosphate**, as it is popularly known. This phosphate source can never suffer the lock-up problems associated with all other phosphates, because of its colloidal nature.

The worst of the acid-treated phosphates, with regard to these lock-up problems is **triple super phosphate**. This product should be avoided at all times. Several of the blended fertilisers include triple super, and growers should avoid all of these blends.

Our colloidal phosphate product, **NTS Soft Rock™** ranks amongst the world's best rock phosphate. The heavy metal cadmium has become a problem with all of the acid-treated phosphates. NTS Soft Rock™ has exceptionally low cadmium levels – less than 1 ppm. The typical analysis includes ~10% phosphorus, 24% calcium, 26% silica and a rich lode of trace elements. NTS Soft Rock™ includes every element known to man (except nitrogen), and they are all in a plant-available, colloidal form.

10. Calcium (Ca)

This element has been termed the "Prince of Nutrients" and is the starting point for any fertility program. Calcium requirements are determined by the specific CEC (cation exchange capacity) of the soil. The formula for determining the ideal calcium levels (in parts per million), for your soil type, is as follows: **CEC x 140** – i.e., in a soil with a CEC of 10, the ideal calcium level will be 1400 ppm, which represents 70% of base saturation. The amount of calcium required to correct a deficiency is calculated on the basis that **1 ppm = 2.24 kg/ha of calcium**. The reason we convert everything to parts per million (ppm) is because the correction of all deficiencies is based upon 1 ppm, equalling 2.24 kg/ha of a particular element.

The type of calcium used is important. The following guidelines may be helpful:

10.1. In high-magnesium, high-pH soils gypsum is often a good choice, particularly if sulfur is also deficient. **Gypsum** has a neutral pH, so it will not raise pH-levels. The sulfate component of gypsum will help to remove excess magnesium. However, it is also wise to consider the fact that magnesium has 1.4 times more effect on pH-levels than calcium. In this context it is actually possible to **reduce pH-levels by adding calcium**. Increasing the calcium base saturation percentage will produce a corresponding reduction in the magnesium base saturation percentage, which will in turn reduce pH-levels – i.e., magnesium has more pH impact than calcium and, therefore, if you can displace it with calcium, you will reduce pH-levels in the process. Gypsum is a more rapid release form of calcium, but it only contains 18 – 20% of calcium. In high-magnesium soils, the best technique to increase calcium, lower magnesium and reduce pH invariably involves a combination of gypsum and **calcium carbonate.**

10.2. Calcium carbonate or **ag-lime** contains the highest level of calcium and is the most cost-effective source of this element. It is important to source a product which is as finely crushed as possible. Lime can take up to two years to release its calcium lode. The finer the product, the faster the release.

10.3. **Dolomite** contains around 20% Ca and 10% Mg.

10.4. Natural Gypsum contains around 20% Ca and 15% S. Chemical gypsum can contain high levels of heavy metals, particularly cadmium.

10.5. **NTS Soft Rock™** includes 24% colloidal calcium.

11. Magnesium (Mg)

Although excess magnesium is literally toxic, this is still a very important element and base saturation percentages should be regularly monitored to maintain the correct balance. Magnesium's main function in plant growth includes the following:

- It is a mineral constituent of chlorophyll.
- It is actively involved in photosynthesis.
- Magnesium aids in phosphate metabolism.
- This element activates several enzyme systems.
- Deficiencies occur most often in coarse-textured acid soils.

In Queensland soils we are usually more concerned with removing magnesium than adding it, but, when it is required, the preferred sources are dolomite, magnesium sulfate and magnesite (magnesium carbonate).

12. Potassium (K)

Potassium has an important role in crop production. It is vital to photosynthesis, essential in protein synthesis, and it improves water use efficiency. It is indeed a major nutrient, but for some reason it has become one of the most overused of all elements. A balanced soil requires 3 – 5% of potassium in the base saturation percentages. In the current K mad environment it is not unusual to witness levels exceeding 15%, and yet there will still be recommendations from some analysts to continue piling it on.

The key to potassium availability is the CEC and pH-levels. Essentially, pH-levels must be **below 6.5** before potassium will build in soils with a CEC **above 7**. There are exceptions to this rule, and they usually relate to the use of manure and compost.

In high-CEC, high-pH soils it is pointless to apply large applications of potassium, as there is no room for potassium to find a place on the soil colloid. Calcium and magnesium invariably occupy all of the available parking spaces. Maintenance doses of **200 kg per hectare** are sufficient in this situation, because any more is simply a waste of hard-earned money.

It is far more productive to try and build potash levels in these soils using manure, compost and microbes to release tied-up potassium. In heavier soils, the amount of "locked-up" potassium can exceed **30 tonnes per hectare**, based on calculations involving the top six inches of soil covering an hectare.

12.1. **Potassium chloride** or **muriate of potash** is the most popular potash source in Australia. It is also the worst. This product should be avoided where possible, as it contains 50% of microbe-killing chloride. However, if potassium chloride must be used due to financial constraints, don't exceed 120 kg/ha in any given application and try to include humates at 2 – 7 kg/ha to help buffer the biocidal effect.

12.2. **Potassium sulfate** is a far better product, and the sulfate content is desperately needed in many cases (42% K, 18% S).

12.3. Other alternatives include **crusher dust** or rock dust, which can include up to 5% potassium, along with many other elements, at a very reasonable price.

Rock dust is most responsive in acidic soils with adequate organic carbon levels. The organic carbon sustains the microbial workers necessary for the release of these rock minerals.

12.4. **NTS Liquid Humus™** includes over 5% potassium. The combination of NTS Liquid Humus™ and a potassium release program (as discussed) can provide considerable benefits.

12.5. The relationship between sodium and potassium is very important. These two elements combined should ideally never exceed 10% of the base saturation. When they total above 10%, they prevent the uptake of manganese. It doesn't matter how good the manganese levels are, it is simply a situation where the manganese uptake is squeezed out by sodium and potassium. Legumes and grains, in particular, will suffer from this manganese shortage. NTS has developed a range of chelated trace elements that will provide a stop-gap solution in these circumstances.

12.6. Another aspect of the sodium/ potassium ratio relates to situations where sodium exceeds potassium percentages on the base saturation table. In this instance, the plant will uptake sodium instead of potassium. Sodium can cause plant cells to expand in hot conditions, bursting the cell walls and causing considerable damage. The lighter the soil, the worse the problem.

12.7. Another feature of potassium imbalance is the fact that any time the potassium base saturation gets above 7.5%, weed pressures increase accordingly.

13. Sodium (Na)

This element is required in small amounts for healthy plant growth – however, in modern agriculture, with the use of high-salt fertilisers and the many salt problems associated with irrigation water, sodium is often excessive and should be removed or buffered. There are several options, which include the following:

13.1. **Gypsum** will open up the soil, allowing the high sodium to be flushed out. The sulfate content of gypsum can also bond with sodium and increase the desired leaching effect.

13.2. **Nutri-Store 180®** with 30% organic carbon can provide a buffer against salt damage.

13.3. **NTS Liquid Humus™** can be very effective against high sodium. Humic acid is a natural buffer providing protection from sodium excesses. It can be added in small doses with irrigation water to help prevent salt damage.

13.4. **Zeo-Tech™ Zeolite** added to the soil at up to 7 tonnes per hectare can provide a very useful storage facility that helps to buffer the effects of high sodium.

14. Sulfur (S)

Sulfur is the most overlooked, major element deficiency in contemporary agriculture. The lack of sulfur is a limiting factor in most of the soil tests we analyse. Sulfur is actually needed in similar amounts to phosphorus. Sulfur competes with phosphorus for absorption and is the loser when phosphorus levels are high. In fact, **high phosphate soils require extra sulfur to compensate**.

Sulfur levels should fall within 30 – 50 ppm, but the amount of sulfur required is dependent on the balance of the cations. If there are excesses, then sulfur will be required in larger amounts to drive out the excesses. When cation equilibrium is achieved, then sulfur needs will level out.

Sulfur is the second most leachable element and in this context, like nitrogen, requirements should be re-assessed yearly.

Sulfur used to be present in rainwater, but environmental regulations have reduced emissions and this is no longer the case. The key to holding sulfur in the soil for longer periods is organic matter. Organic matter is the sulfur storage medium. The use of **Nutri-Store 180®** will help hold sulfur in the soil more effectively..

14.1. The Gypsum Problem

Gypsum is undoubtedly the most cost-effective source of sulfur, but there is an escalating problem associated with the use of chemical gypsum – the by-product from the manufacture of acid-treated phosphates. Chemical gypsum has higher levels of the heavy metal **cadmium**. The export market is becoming increasingly sensitive to the presence of cadmium in all vegetable, fruit, grain and meat products. The crops most at risk are root crops, which are more prone to accumulate heavy concentrations of cadmium. Cadmium stays in the soil for up to 1,000 years, so if you are a heavy gypsum user, perhaps you should be reconsidering your options.

14.2. The Gypsum Solution

We have sourced an excellent natural gypsum from Queensland's central West. This has a very similar analysis to chemical gypsum, but it is **cadmium-free**. Natural gypsum is more expensive in some areas, due to the transport component. When considering the price differential, it should be noted that chemical gypsum contains up to 40% moisture, which has a big impact on the amount of actual gypsum you are receiving for your dollar. It's hard to put a price on potential toxic degradation of any soil, but it is certain that growers of root crops should not be using chemical gypsum.

14.3. What Does Sulfur Do?

14.3.1. Sulfur is essential for the synthesis of enzymes and vitamins. Fruit quality is directly related to this function. All fruits are vastly improved in taste and keeping quality when sulfur is supplied in appropriate quantities. This element also improves the palatability of grasses and fodder crops.

14.3.2. Sulfur increases the protein content of crops (this is particularly relevant in legumes such as lucerne, soybeans etc).

14.3.3. Sulfur provides increased root development. It can obviously provide considerable improvements to crops like potatoes, peanuts and carrots, but all plants will appreciate improved root structure.

14.3.4. Sulfur helps seedlings survive in cool, moist conditions. It is ideal for early plantings.

14.3.5. Sulfur is the fourth major nutrient in terms of the amount required by most crops.

14.4. Sulfur Sources:

- Gypsum, ammonium sulfate, potassium sulfate, trace elements in the sulfate form, elemental sulfur and super phosphate.
- **Natural Gypsum** contains 150 kg of sulfur per tonne.
- **Nutri-Store 180®** contains 25 kg of sulfur per tonne. The sulfur content of Nutri-Store 180® will not leach as readily as other sources, as it is complexed by the composting process. The 30% organic carbon in Nutri-Store 180® is also a sulfur storehouse for any other added sulfur.
- **NTS Liquid Humus™** will also help hold sulfur in the root-zone, and it is an excellent adjunct to gypsum.

15. Trace Elements

These elements are measured in minute quantities, but their importance should never be judged in terms of the extent to which they are found in soil and plants. The smallest application can sometimes produce tremendous improvements.

Cation imbalance can dramatically effect the availability of trace elements, and therefore it is important to deal with these problems first. In fact, we never deal with trace elements until major and secondary elements are properly in place. Calcium should always occupy at least 60% of the base saturation before we turn our attention to the "traces".

The most graphic illustration of the interaction of essential elements is called **Mulder's Chart** (Figure 15.1).

Mulder's chart demonstrates the phenomenon of **antagonism** and **synergism**. When an element interferes with or prevents the uptake of another, it is called **antagonism**. When one element increases the availability or uptake of another, it is described as **synergism**.

This chart can be a particularly valuable guide in explaining leaf analysis data and in deciding upon appropriate programs. If you have any major excesses, this chart can be used to delineate any potential lock-ups. E.g., excess calcium will affect the availability of magnesium, zinc, iron, potassium and manganese – a good reason to avoid over-liming.

Mulder's chart graphically highlights some of the complex inter-relationships between the different elements. It also illustrates the critical importance of **balance**. The simplistic N-P-K concept, involving copious amounts of just three elements piled on indiscriminately, is revealed to be hopelessly inadequate when we consider these complex relationships.

In this context, the symptoms of a particular deficiency may not mean that there is a shortage of the element in question. It is more often the case that excesses of other elements have shut down the availability of the element that appears to be deficient.

Iron is a good example. **Chlorosis** is a condition that suggests an iron deficiency, but the soil analysis will invariably suggest otherwise. The fact is that iron deficiency can be induced by too much calcium or too much zinc, copper, manganese or phosphorus (see Figure 2). These elements in excess are **antagonistic** to the uptake of iron. The fascinating thing here is that the problem can be solved without the addition of iron. In fact, in this case, the addition of a completely different element – potassium, which stimulates iron uptake – can solve the iron deficiency problem. Professor Mulder's chart should be kept accessible for easy reference, so you can gain maximum benefits from this enlightening information.

15.1.

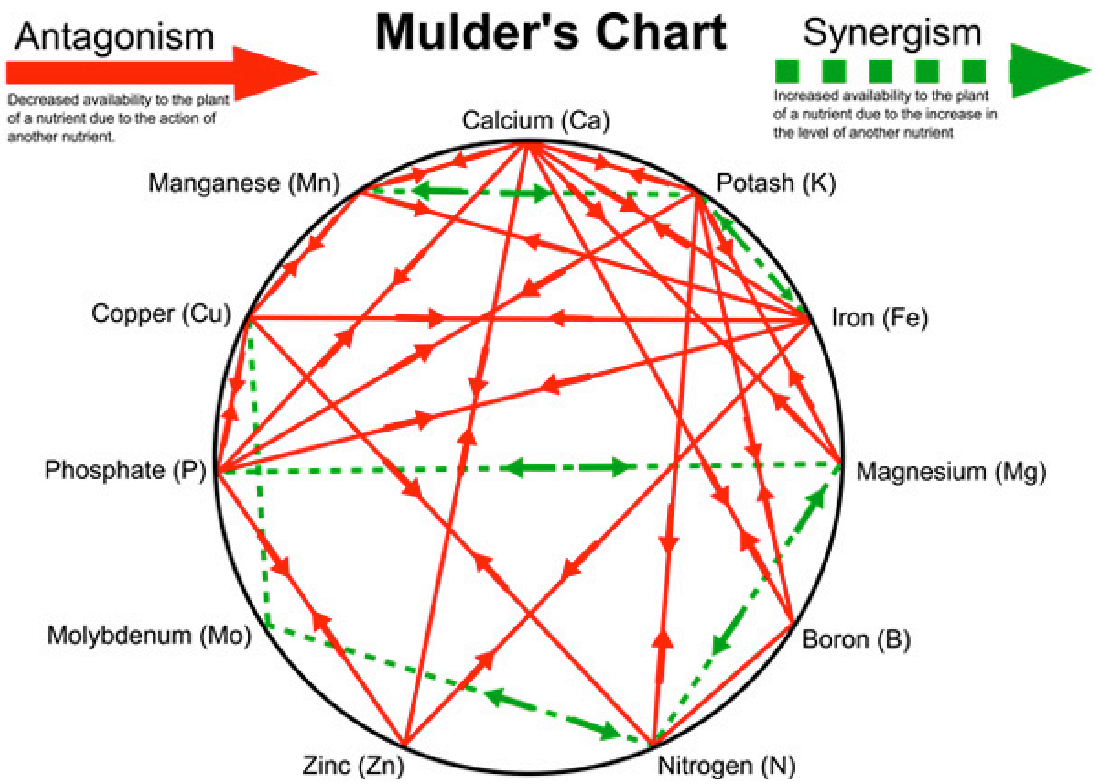


Figure 2: Mulder's Chart

15.2. Trace Element Sources

15.2.1. Micro-nutrients in the sulfate form – i.e. iron sulfate, manganese sulfate etc.

15.2.2. Nutri-Key Shuttle® Range – Chelated trace elements using the Shuttle® system to deliver nutrients directly to the plant. The Shuttle® system is a major breakthrough in chelation nutrition. In conventional chelation chemistry, agents like EDTA or Ligno-Sulfonates carry the desired trace elements through the outer walls into the plant. By contrast, the Shuttle® system involves much more than a one-way journey, and the chelator never actually enters the plant. A suite of natural, polysaccharide-based agents are utilised in a two-step process where the selected elements are sequestered or held in reserve in structures called nano-clusters. A Shuttle® ligand chelator then transports the nutrients to the plant surface where it docks and unloads its cargo before returning to the pool of sequestered clusters to repeat the exercise again and again. The net effect is a greatly enhanced uptake of the desired nutrients.

15.2.3. Nutri-Store 180® – Includes good levels of a wide range of trace elements, all complexed into the composted product to ensure stability and plant-availability.

15.2.4. NTS Soft Rock™ – Contains up to 5 times the trace element levels of the rock mineral fertilisers, and all in plant-available, colloidal form.

15.2.5. NTS Liquid Humus™ – This humic acid has natural chelating capabilities, which will increase the availability of all added trace elements. Perhaps the most significant feature of NTS Liquid Humus™, in the trace element context, is this product's remarkable ability to unlock "tied-up" traces. It is a highly effective nutrient-releasing agent, providing output far in excess of the input.

These unique products provide considerable benefits as stand-alone fertilisers, but, when included together in an appropriate program, they are incomparable. There is a synergistic effect involved with these combinations, which is usually more biological than chemical in nature.

15.3. The Law of the Minimum

Von Liebig's Law of the Minimum is important when considering trace element needs. This law states that plant growth and yield is governed by nutrients in the least supply, not by those in abundant supply. As a plant goes into its time of stress – the time when it produces the part the grower sells – it is not the abundant supply of nitrogen or potassium that will determine yield, but the nutrient which is most deficient. Invariably, this involves one or more of the trace elements, as they are the most ignored. It is often not feasible within this critical time-frame to isolate the offending deficit(s) (via leaf analysis). Often the most productive technique is to adopt the "scattergun" approach and cover all bases. This "scattergun", broad-spectrum approach must involve a foliar fertiliser, as this is the only way to provide the trace elements exactly when they are needed.

The NTS solution in this case is **Tri-Kelp™**. Tri-Kelp™ contains every conceivable trace element as well as auxins, gibberellins and cytokinins – potent, naturally-occurring growth promoters, which are responsible for seaweed's reputation as the world's fastest growing plant (up to 25 cm per day). These growth promoters can be successfully translocated to produce accelerated growth and increased flowering and fruiting in any other plant species.

16. BORON (B)

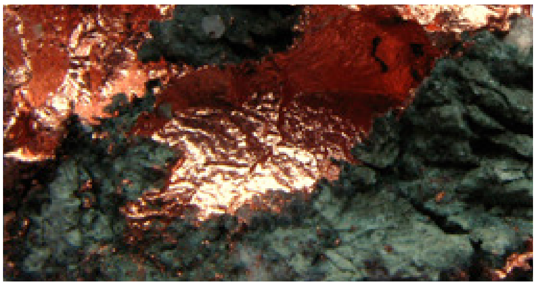
Boron is responsible for good seed set, translocation of sugars, cell division, the regulation of flowering and fruiting, and the uptake and efficient use of calcium.

Boron is a leachable element and therefore requires constant monitoring to ensure adequate levels are present. It is one of the most neglected trace elements, due to a misapprehension that it is only important in lucerne and tuber crops. This is a serious mistake, as boron is required at **1 ppm to 3 ppm** for all field and tree crops. Boron can be toxic, particularly in a situation involving low calcium levels. For this reason it should always be broadcast rather than used in starter bands, unless it is stabilised with a humate as in **NTS Stabilised Boron Granules™**. It can also be applied as a liquid product and as a foliar, where it should ideally be combined with calcium. **Solubor/Inkabor** is a good soluble boron source suitable for foliar sprays and putting through fertigation whenever instant boron is required.

Low pH increases boron solubility and can increase the risk of toxicity (see Figure 1). High pH reduces boron availability, as does an organic carbon deficiency. In high-pH, low-humus soils, the foliar alternative is essential to ensure adequate boron. High potassium will also tie up boron. Due to the leachable nature of boron, the best time to make applications is about six to eight weeks before planting.

Products in the NTS range that supply boron include:

NTS Stabilised Boron Granules™ .... ~3%
Inkabor (soluble boron) 22%
Nutri-Key Boron Shuttle™.................. 4.7%
Nutri-Key Tri-Shuttle CBZ™............. 0.32%
Nutri-Key Tri-Shuttle BIZ™ 3%
Trio™ (CMB).................................. 0.26%
Cal-Tech™ 0.4%



17. COPPER (Cu)

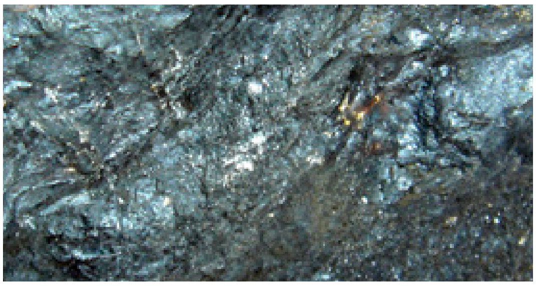
Copper has been almost completely ignored in general agriculture, yet it plays several important roles in plant growth and reproduction. Copper is the element linked to protection from fungal disease. It also increases stalk strength and elasticity, improves seed production and helps increase the sugar content of both fruit and vegetables. Copper increases the uptake of ammonium nitrogen and is essential to chlorophyll formation in plants.

Copper sulfate is the best form to use for building copper levels in the soil. Chelated foliars can provide stop-gap solutions, but it is a good idea to build soil levels, as copper is a very stable element and good levels can be easily maintained.

Excess phosphorus can "tie-up" copper, and the reverse is also true (see Figure 2). Excess copper levels will mandate the use of additional phosphate to prevent "tie-ups". Excess nitrogen also stops the uptake of copper.

Products in the NTS range that supply copper include:

Copper Sulfate 25%
Nutri-Key Copper Shuttle™ 7.6%
Nutri-Key Tri-Shuttle CBZ™................ 2.1%



18. IRON (Fe)

Iron is needed for chlorophyll and protein synthesis. It is involved in photosynthesis and plays a major role in the oxygen carrying system. A lack of iron causes a yellowing or iron chlorosis, due to the lack of chlorophyll.

Iron sulfate can be used to correct soil deficiencies. Use **ferrous sulfate** rather than **ferric sulfate**. However, the most cost effective form is by using **Nutri-Store 180®** or **NTS Soft Rock™**, which are both iron-rich products.

Excessive iron does not appear to be a problem. Soils with 3000 ppm can produce as well as soils with 300 ppm iron.

Most soils have between 10 tonnes and 100 tonnes of iron in the top six inches of a hectare. In this context, there is considerable potential to free up iron with a nutrient release program.

The correction of pH-levels through balancing base saturation levels will also increase iron availability.

18.1. There is a link between manganese and iron. Iron should always be higher than manganese for maximum results.

Products in the NTS range that supply iron include:

Nutri-Key Iron Shuttle™........................ 7%
Nutri-Key Tri-Shuttle ZIM™.............. 2.38%
Nutri-Key Tri-Shuttle BIZ™ 4%
Nutri-Store 180® 2.7%
NTS Soft Rock™ 2%

19. MANGANESE (Mn)

Manganese accelerates germination and hastens fruiting and ripening of crops. It is important in the assimilation of nitrates and is essential for the assimilation of carbon dioxide in photosynthesis. Manganese is also an essential part of plant enzyme systems and is directly involved in uptake of iron and ascorbic acid. Manganese availability is greatly reduced by high soil pH or cold soil conditions.

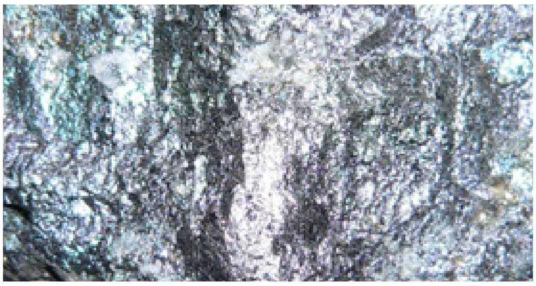
Excessive base saturation of potassium and sodium (higher than 10% when combined) will shut out manganese. It doesn't matter what the soil test reports in this case. Manganese uptake will be blocked. This problem often occurs in lighter soils and can be an unrecognised yield-limiting factor for cotton, wheat, soybeans, peas, oats, tomatoes, citrus and grapes.

Broadcasting **manganese sulfate** is the best way to build soil levels. Manganese chelates can be an effective stop-gap solution, but they can never build soil levels. Low sulfur levels can also cause less manganese availability. Ammonium sulfate can help increase manganese availability, particularly in alkaline soils.

A soil analysis is always required to determine manganese requirements. This is very important in low-pH soils, as manganese toxicity is possible in soils with pH-levels of below 5.5. Raising pH-levels from 5.5 to 6.5 decreases the amount of manganese available in the soil solution by 100 times.

Products in the NTS range that supply manganese include:

Manganese Sulfate 25%
Nutri-Key Manganese Shuttle™ 14%
Nutri-Key Tri-Shuttle ZIM™.............. 2.95%



19.1. Hidden Hunger

In terms of the amount needed and the effect on all crops, manganese could be called the most important of all micro-nutrients. Often, when levels are borderline, the deficiency is not apparent on the leaves (manganese deficiency is similar to magnesium deficiency, involving yellow leaves with dark green veins). This phenomenon, when deficiencies are not obvious but they still affect yields, is called **hidden hunger**, and it is a major problem with trace elements. Hidden hunger, involving micro-nutrients, is responsible for many yield reductions of which growers remain blissfully unaware. The weather or the season is blamed for poor performance when, in most cases, trace element deficiencies are the key.

20. ZINC (Zn)

All plants need zinc for normal growth and reproduction. Zinc governs the production of auxins, which determine leaf size. This element, therefore, has a huge impact on crop yield and applications have proven to give the greatest response of any trace elements in terms of cost:benefit ratio.

Zinc aids in the absorption of moisture, regulates plant sugar use and is involved in protein synthesis. The minimum level for zinc is **5 ppm**, while a good level is **10 ppm**. Many soils are below this minimum and, in our experience, added zinc can provide an exceptional response.

Excess nitrogen ties up zinc. High phosphorus, calcium or potassium levels will contribute to zinc deficiency, and high pH-levels can also reduce the availability of zinc.

Zinc sulfate contains 34% zinc, and it is the best product to build soil levels. 10 kg of zinc sulfate will increase levels by 2 ppm.

Zinc is fairly stable in the soil and, in this context, it is possible to gradually build levels with light applications, if it is not financially feasible to address the deficiency in one application (i.e., broadacre situations).

Products in the NTS range that supply zinc include:

Zinc Sulfate **34%**
Nutri-Key Zinc Shuttle™ **8%**
Nutri-Key Tri-Shuttle ZIM™ **4.18%**
Nutri-Key Tri-Shuttle BIZ™ **7%**

20.1. Fast Track With Foliars

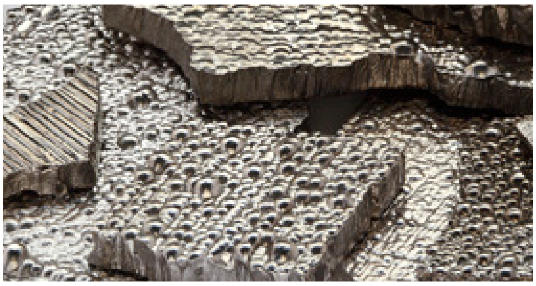
Foliar applications are necessary in orchard situations, because of the difficulty of getting broadcast zinc into the root-zone. If the leaf analysis for any crop highlights a deficiency or lock-up of any element, then the foliar route is the fastest way into the plant. In general, it is preferable to build trace elements in the soil and use foliar application as a salvage tool. In the long term it is far more cost-effective to build and maintain adequate soil levels of all trace elements.

21. MOLYBDENUM (Mo)

Only a small percentage of tests check levels of this element, but it, too, can be a limiting factor. Molybdenum is the only micro-nutrient for which availability increases as the pH-level rises (see Figure 1). This element is associated with nitrogen fixation and nitrogen metabolism within plants. If levels fall **below 0.4 ppm** (total Mo), then this trace element can limit yields. Molybdenum can be very responsive with citrus trees. If levels are below 0.4 ppm, the appropriate application will often produce good yield increases.

Products in the NTS range that supply molybdenum include:

Sodium Molybdate **39%**
Nutri-Key Moly Shuttle™ **4.8%**



22. COBALT (Co)

Cobalt in small amounts is essential to many living organisms, including humans, because it is a central component of vitamin B12. Cobalt is used to treat anaemia in pregnant women, because it stimulates the production of red blood cells. The total daily intake of cobalt is variable and may be as much as 1 mg, but almost all will pass through the body unadsorbed, except that in vitamin B12.

Cobalt is important in the plant world. Bacteria on root nodules of legumes (beans, alfalfa, clover) require cobalt (and other trace elements) to synthesise B12 and fix nitrogen from air. Soybeans grown without cobalt are severely retarded in growth and exhibit severe nitrogen deficiency, leading to death in about one of four plants. Adding only a few hundred grams of cobalt per hectare can resolve deficiency symptoms in 10 – 21 days.

Cobalt deficiency is far more dramatic in animals, particularly ruminants (cattle, deer, camels, and sheep) grazing on deficient pasture. These animals obtain all of their B12 from their gut bacteria, but only if bacteria are provided cobalt from pasture. Legumes with less than 80 parts per billion (ppb) cobalt can't meet ruminant B12 needs.

Products in the NTS range that supply cobalt include:

Nutri-Key Shuttle Seven™................35ppm
Triple Ten™ 1.4ppm
Life Force® Total Cover™....................8ppm

23. Fertility Rating

★ **VERY POOR**

★★ **POOR**

★★★ **ADEQUATE**

★★★★ **GOOD**

★★★★★ **EXCELLENT**

The Soil Therapy™ fertility rating is a calculated rating of the growing power of your soil. Cation balance, organic matter levels, deficits and excesses of major and minor elements and likely microbial activity are all considered in the computation of your rating. Soil types and inherent soil problems are also factored into the equation. ½ stars are used for more precise ratings. "Excellent" ratings are only achieved in about one out of every 500 tests we analyse!

Soil Therapy™ has now been available for sufficient time to have enabled repeat analyses on the same block. This provides us with the opportunity to see how we are performing. The results to date have been nothing short of spectacular, involving fertility increases that would not normally be possible in a single season.

24. Conclusion

It is our hope that this overview of nutrient requirements will provide a better understanding of our recommendations. A lack or excess of any element has a direct impact on the soil and all that live from it.

Three words summarise the philosophy behind Soil Therapy™:

BALANCE IS EVERYTHING!