Plant Nutrition: Alternates, substitutes or the fundamentals done well

There seems to be another resurgence of alternates or substitutes for fertiliser out there at the present time. This is typical when the fertiliser budget is stretched and farmers are looking for that silver bullet. These alternative approaches often claim to solve all nutrient problems. When spending your fertiliser dollar it is critical to consider the following.

Fact 1: Plants need Essential Elements for growth.
Plants are known to contain a wide range of chemical elements and it has been shown that many of these are essential for plant growth. Essential elements (or nutrients) are defined as those which are required for the normal life cycle of the plant and whose function cannot be substituted by other chemical compounds and are directly involved in the nutrition of the plant.

The essential nutrients needed for plant growth of higher plants is shown in the table below.

In addition to these nutrients, plants contain many other elements. Some are known to be toxic to plants and animals if present in high concentrations, e.g. aluminium, lead and nickel.

The nutrients in the plant are present as components of a wide variety of chemical compounds. The most abundant compound is water (H_2O) which accounts for approximately 70% of the total fresh weight of the plant. The bulk of the plant dry matter consists of organic compounds based on carbon, oxygen and hydrogen, e.g. proteins and carbohydrates, with less than 10% of the dry matter made up of the mineral nutrients. Plant nutrient composition is usually expressed on a dry weight basis and typical ranges are given in the table below. Nutrients are separated into macronutrients and micronutrients (trace elements) depending on the relative amounts found in the plant. Macronutrient concentrations are usually expressed as percentages of the dry matter (%DM) and micronutrients as micrograms per gram (µg/g).

Carbon, oxygen and hydrogen are supplied in large quantity by the atmosphere, water and also by the soil organic matter. The other nutrients are held and supplied by the soil. Nutrients are also applied in fertilisers, because soils are unable to supply all the plant nutrients at a rate for optimum plant growth.

Element		Typical concentrations	Forms taken up by the plant
Carbon	Macronutrients		CO_2, HCO_3^-
Hydrogen			H_2O
Oxygen			O_2, H_2O
Nitrogen		2.0-4.0%	NO_3^-, NH_4^+
Phosphorus		0.1-0.4%	$H_2PO_4^-$, HPO_4^{2-}
Potassium		1.0-3.0%	K^+
Sulphur		0.2-0.5%	SO_4^{2-}, SO_2
Calcium		0.5-3.0%	Ca^{2+}
Magnesium		0.1-0.5%	Mg^{2+}
Sodium*		0.2-1.5%	Na^+
Iron	Micronutrients (trace elements)	50-300 µg/g	Fe^{2+}
Manganese		20-250 µg/g	Mn^{2+}
Zinc		20-100 µg/g	Zn^{2+}
Copper		5-15 µg/g	Cu^{2+}
Molybdenum		<0.1-1.0 µg/g	MoO_4^{2-}
Boron		10-50 µg/g	H_3BO_3
Chlorine		0.2-2.0 µg/g	Cl^-
Silicon*		0.2-2.0 µg/g	H_4SiO_4
Cobalt*		0.04-0.4 µg/g	Co^{2+}

(*not demonstrated to be essential for higher plants).

Fact 2: If an essential element is limiting, then plant growth is restricted.
If any one of the essential nutrients is in short supply or absent from the soil then plant growth is restricted. Additions of increasing amounts of the deficient nutrient to the soil will result in improved plant growth until that nutrient is no longer the limiting factor. The nutrient concentration in the plant will also increase as the nutrient is added to the soil. The plant nutrient concentration at which no further increase in plant yield is obtained, from adding the nutrient is referred to as the critical nutrient level. This value is sometimes used as an aid to the diagnosis of plant nutrient deficiencies and assessing the effectiveness of the fertiliser programme. Although plant yield will not be increased further once the critical nutrient level is reached, the nutrient concentration itself will continue to rise in response to nutrient additions. Uptake of nutrients above the critical level is termed luxury uptake. With some nutrients, further additions above this point may result in yield depression occurring.

If two elements are limiting growth, adding only one of them will have little effect, while adding both together will lead to a large increase in plant production. This can be common with phosphorus and sulphur when both are limiting. Adding just phosphorus will have little effect and therefore a poor use of money. But if sulphur is added with the phosphorus the results are significant.

Fact 3: Not all soils are created equal.
The total amount of many nutrients present in the soil is determined by the original composition of the parent material. Greywacke for example has a relatively low phosphorus content compared with limestone or basalt.

The release of nutrients from the parent material minerals depends on the extent of weathering of the soil. Once released from within a mineral structure the individual nutrients can either be taken up by the plant, held on exchange sites, utilised by micro-organisms and held in the organic fraction or they can be leached from the soil. A ‘recent’ soil derived from unweathered parent material will generally have a higher fertility than one which has experienced intensive leaching over a long period of time. A soil of an intermediate age will have more organic matter and a greater degree of mineral decomposition than a recent soil. This usually means that nutrient release and cycling is more intensive in intermediate aged soils than in recent soils.

Other soils such as allophanic soils can absorb nutrients such as phosphates, limiting their plant availability.

Fact 4: Soil pH effects nutrient availability.
Acidic soils reduce the availability of some base cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and cause high concentrations (often at toxic levels) of some micronutrient cations (Fe^{2+} , Cu^{2+} , Mn^{2+} and Zn^{2+}). In acid soils high levels of soluble iron and manganese can reduce plant growth directly or through their effects on the availability of other nutrients especially phosphorus. Aluminium is also higher under low pH. Lime can reduce the levels of these nutrients.

Molybdenum availability decreases as soil pH also declines. The main reason for liming some New Zealand soils is to increase the availability of Molybdenum to clovers in order to increase nitrogen fixation. Phosphorus and nitrogen availability is also limited under acid conditions.

Fact 5: Clovers are important in the New Zealand pastoral system
In New Zealand the grass/clover pasture obtains its nitrogen supply almost entirely from the clovers. Consequently P, K and S, lime and Molybdenum are applied to encourage clover growth and promote N fixation by the Rhizobium bacteria. The nitrogen made available from the bacteria in turn stimulates grass growth and increases total productivity. P, K and S, along with N supplied by the clovers are also needed by the grasses.

Summary

1. Plants require the essential nutrients for plant growth. If one is limited then plant growth is restricted.

2. Any fertiliser mixture you are considering needs to satisfy the level of essential nutrients required for plant growth. You need to calculate the amount of nutrient in the fertiliser options you are considering against your needs and also the cost of each of them on the ground.
3. Operating with all your soil nutrient levels at optimum levels should be the ultimate goal in the nutrient management component of you soil management plan.