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Principles of nutrient management

A - Soil balance

1 - Chemical soil testing (laboratory analysis) = essential

Chemical soil testing gives information about potential nutrient availability.

- Macronutrients nutrients – available N, P, K, S, Ca, Mg, Cl, Na (Na and Cl may be harmful at high levels)
- Nutrient ratios e.g. Ca/Mg, K/Mg
- Micronutrients (trace elements) – Fe, Zn, Mn, Cu, B, Mo, (Co, Se e.g. for pasture)
- fertility indicators – organic carbon, electrical conductivity - EC, acidity or alkalinity - pH, nutrient holding capacity (e.g. cation exchange capacity – CEC), texture (sand, silt, clay)

2 - Soil microbial testing (laboratory analysis) = optional

Soil microbe levels and ratios may give additional information about the soils ability for nutrient cycling and potential crop nutrient uptake efficiency. They also give an indication on the physical condition of the soil e.g. water logging, compaction)

3- Soil physical testing (laboratory or in field analysis) = essential

Soil physical condition refers to soil structure and the soils ability to provide a balanced environment for plant roots and microbes in terms of moisture, air and access to nutrients. Compacted soil is in poor physical condition; air and water holding capacity as well as infiltration rate are reduced, and there is a high resistance to root penetration. This means that the crop can only exploit a small soil volume for water and nutrients. The soil dries and gets waterlogged easily, stressing the crop. Some indicators for physical soil health are:

- resistance to penetration (shear strength)
- bulk density
- aggregate stability
- infiltration rate
- pore size distribution

Laboratory analyses are time consuming and expensive. ***However, a visual soil assessment using a spade is usually all that is needed.***

The most important management strategies for maintaining or improving all soil properties are maintaining or increasing organic matter (carbon) levels and avoiding compaction and erosion!

B - Nutrient budgeting – fertiliser plan

When implementing a nutrient budget you have to consider specific variety (e.g. vigour, rooting habits) paddock (soil structure, rotation) and environmental conditions (soil type, climate).

Nutrient Uptake – all nutrients taken up from the soil (or via foliar fertilisers) by the crop

Nutrient Removal – all nutrients removed from the paddock with harvested fruit

Nutrient Recycling – all nutrients returned to the soil with crop residues after harvest

Nutrient Losses – Leaching, denitrification volatilisation, nutrient fixing by soil minerals, nutrient interaction or by microbes

C - Crop nutrition monitoring

The crop is monitored to check that the fertiliser plan is working and fine-tune applications to avoid deficiencies.

Decision guides for soil assessments, testing and goals

If soil assessments show that the soil is not in the required condition, it is important to devise actions to be taken to makes changes. It is a good ides to record the proposed actions and by when they should be completed and what out come is expected.
The following tests can help you to monitor the health of your soil, its suitability for crop production, nutrition and irrigation requirements and environmental impacts.

Where needed, test your subsoil as well as your sub-surface and topsoil.

Consider the type of testing that you need:

- Visual inspection
- Field-based testing
- Laboratory testing

Issue		**Test**
Soil condition	Soil structure	degree of compaction assessment, spade or penetrometer
		Soil structure scoring - cloddiness
		Stability (when water is added)
		Resilience (potential to regenerate after soil has been compacted)
	Soil water	Soil moisture
		Depth to water table
	Soil organic carbon	Soil organic carbon
	Soil biodiversity	Population analysis (eg worms & critters, fungi, bacteria etc)
		Biological activity
		Indirect indicators (eg soil organic carbon)
	Erosion	Visual inspection
		Measure area and depth of soil loss
		Water turbidity
	Soil and water salinity	Electrical conductivity
		Depth to water table
		Visual inspection or measurement of salt-affected land
	Soil sodicity	Exchangeable sodium percentage (ESP) of soil and irrigation water
	Soil acidity/alkalinity	pH
Nutrition	Nutrient needs	Soil, water and plant testing
	Contaminants	Compost contaminants eg weed seeds
		Fertiliser contaminants
	Soil acidification potential	Fertiliser acidification potential
	Salinity	Salt Index of fertilisers
Water quality	Fertiliser pollution	Irrigation depth, soil nutrient testing, water quality testing
	Sediment pollution	Water turbidity, iron levels, nitrogen and P levels in water

Nutrient budgeting

Soil testing and subsequent nutrient budgeting are basic tools for the development of a nutrient management plan.
The macronutrients nitrogen, phosphorus, potassium sulfur, calcium and magnesium are the elements usually considered in nutrient budgeting. Visual assessments and plant testing are in-crop monitoring tools for fine tuning the fertiliser program during the season.

A nutrient budget can be prepared for a 3-5 year rotation. Break or cover crops should be considered as 'catch crops' against nutrient losses. Nutrients that have not been used by the previous crop will be taken up by the break crop, thus avoiding leaching past the rootzone.

A nutrient budget is like an accounting system for nutrients. It involves:

- Estimating the amount of nutrients available or lacking form the soil (soil test results). The prerequisite for successfully working with nutrient budgets is a balanced soil (physically, chemically, and biologically)
- Obtaining uptake and removal figures for the target crop and the previous crop (to account for nutrients in crop residues). Uptake and removal figures should be in kg/tonne of crop grown (for uptake) and harvested (for removal) or recycled nutrients (crop residues)
- Determining the target yield to calculate actual uptake and removal figures
- Estimating the amount of nutrients from a previous cover crop or crop residues,
- Determining the amount of nutrients applied with manures, if used
- Calculating the amount of nutrients, especially nitrogen, that may be applied with irrigation water (50ppm nitrate in irrigation water will add about 1kg N /ha with every 10mm of irrigation water applied)
- Calculating the amount of nutrients already applied to a paddock, if applicable
- -Estimating possible nutrient losses through leaching, fixing, volatilisation or soil erosion,

The aim of the budget is to replace nutrients lost to the system via crop removal (harvest) under consideration of the above mentioned factors through well timed fertiliser applications. Nutrients that may be easily lost have to be applied as frequently as possible and amounts should be matched to the crop growth curve (rapid growth = higher demand).

Factors affecting nutrient uptake

Introduction

The following factors need to be considered in a holistically. Each factor interacts with several or all of the others. Seasonal changes will also play a part in how these factors will interact with each other, affecting nutrient utilisation.

Soil pH

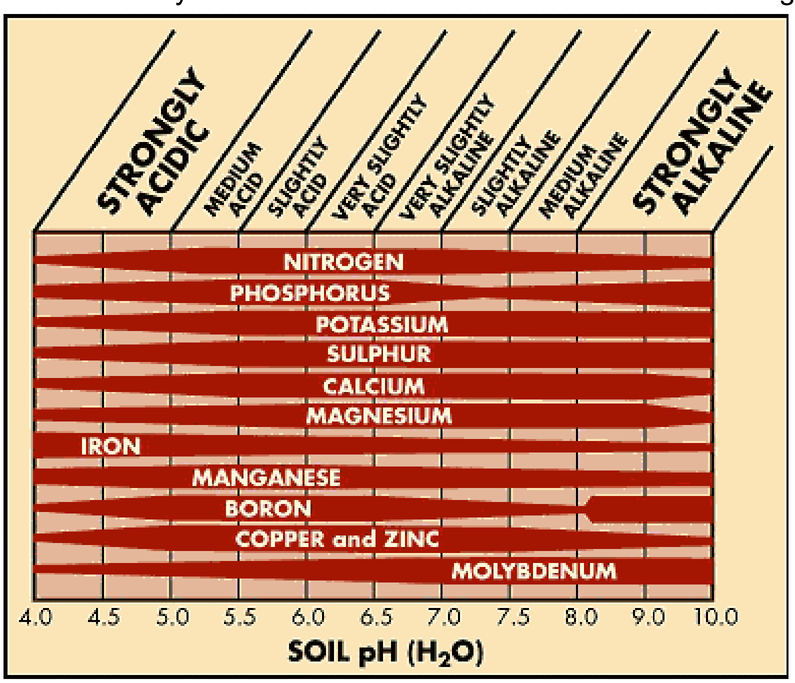
Soil pH greatly influences the growth and yield of plants. This is largely a result of chemical reactions in the soil influencing nutrient availability and uptake.

Soil pH greatly affects the solubility of nutrients. The majority of essential plant nutrients are obtained from the soil. Before plants can use a nutrient it must be dissolved in the soil solution. Most nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils.

Phosphorus is never readily soluble in the soil but is most available in soil with a pH range around 5.5 to 6.5. Extremely and strongly acid soils (pH 4.0-5.0) can have toxic concentrations of soluble aluminium, iron and manganese, while having low levels of calcium and magnesium. The pH range for most readily available plant nutrients is around pH 6 to 7.

The soil pH can also influence plant growth by affecting the activity of beneficial micro-organisms. Bacteria that decompose soil organic matter are suppressed in strongly acid soils. This prevents organic matter from breaking down, resulting in an accumulation of organic matter and the tie up of nutrients, particularly nitrogen, which are held in the organic matter and would become available through mineralisation under neutral conditions.

Contact us if you would like to find out more about the testing of soil microbial indicators.



Nutrient availability as affected by soil pH; the wider the band, the greater the availability or activity.

Soil texture and type

When making predictions about the nutrient uptake of a crop, it is essential to know about the soil type, and how it can interact with the availability of nutrients. Generally, higher the levels of organic matter and clay in a normal pH range indicate a good nutrient holding capacity.

Sandy loam, Sand

Sandy soils are well drained and aerated. Without high organic matter content, and having an open structure, they are prone to drying out quickly and may require frequent irrigation. Extra fertiliser maybe required due to the additional irrigation and possible leaching. They are often referred to as “hungry” soils because of their low nutrient holding capacity. With careful management however, they can be amongst the most productive soil types. They are easy to work, and warm up quickly during warm weather.

Medium Loam, Sandy Clay Loam, Silt Loam

These are the soil types usually very well suited to cultivation but compact more easily than sand. They achieve a good balance between the ability to be very productive and the amount of attention required. The medium loam group is probably the best cropping soil texture in this respect.

Clay, Sandy Clay, Clay Loam

These soils are referred to as fertile soils, due to their ability to hold nutrients on soil particle surfaces. The main drawback is the usually high water holding capacity, which restricts the nutrient mobility and may keep these soils cold in spring. Waterlogging and compaction may occur more easily than in lighter soils.

Chalk, Limestone Rich

Limestone soils may be deficient in micronutrients and phosphorus due to a high pH. These soils are often very shallow, and severely limit the types of plants that can be grown successfully in them.

Organic Soils

Manganese, copper and zinc may be unavailable to plants in organic soils due to strong bonding qualities of the organic particles. Organic soils are often acid and not suitable for a wide range of crops.

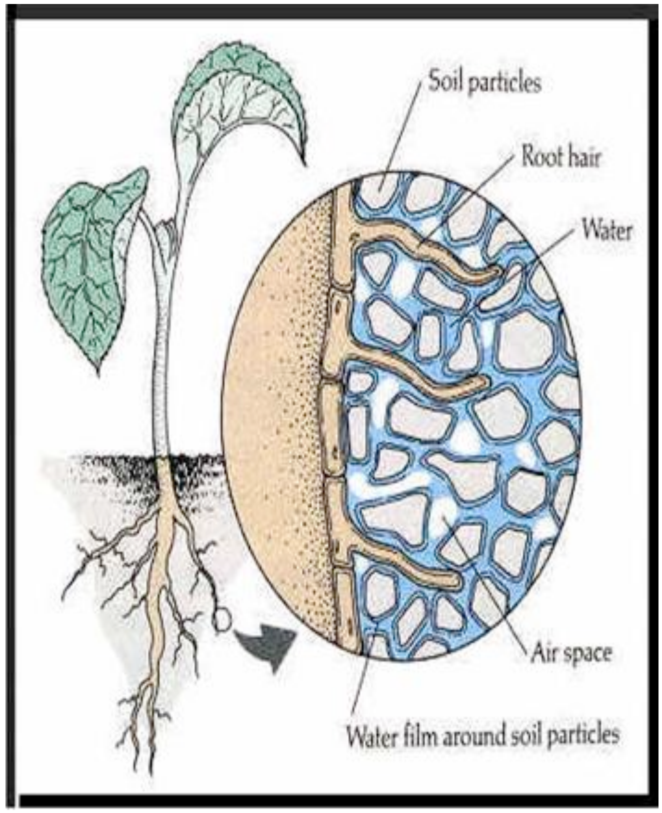
Soil physical properties or structure

Poorly structured or compacted soils restrict root growth and thus access to nutrients and water. Drainage is reduced, leading to potential temporary waterlogging after rain or irrigation. On the other hand, compacted soils dry out fast needing frequent light irrigation applications. They also are more prone to higher pressure from soil borne diseases and a lower microbial activity.

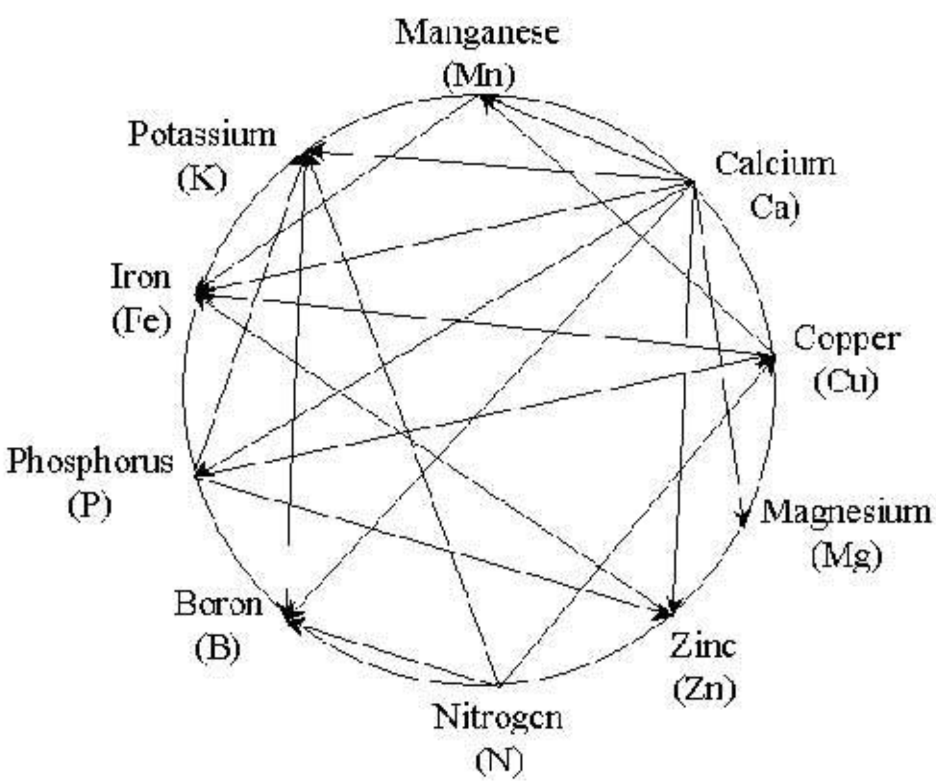
Root length density

The more active, healthy roots you have per plant, the larger the soil volume they can explore, the better the nutrient uptake.

Root soil interaction



Nutrient interactions in soil



In Summary

Prerequisites for a nutrition program to work are good soil structure and root distribution as well as appropriate soil moisture management. Organic matter management has to be part of the nutrition management program. If soil structure, root growth and or irrigation water quality are below optimum, nutrient availability and/or uptake will be affected.

A fertiliser program has to specify the timing, amounts and types of nutrients to apply.
Too little, too much fertiliser, wrong timing or nutrient imbalances will affect crop yield, quality, health and profitability.

If fertiliser amounts, timing or type are not optimum for the situation, they may als contribute to off-site degradation of groundwater and waterways, increase soil acidity, salinity and sodicity problems and soil contamination (e.g. heavy metals).

Inorganic fertilisers are only one method for supplying nutrients. Cover crops, fallow crop residues and animal manures release significant amounts of nutrients as they break down and add organic matter to the soil. For example crop residues from a cauliflower crop contain about 170kg N, 27kg P and 180kg K per hectare. The amount of nutrients retained in crop residues can be calculated by subtracting nutrient removal figures (removal from the system with harvest) from nutrient uptake figures (nutrient uptake into all plant parts).
Animal manures can add significant amounts of phosphorus to the soil. Manures should be tested for nutrient content, chlorine levels, electric conductivity (salinity), pH and presence of contaminants such as heavy metals before application. Weed seeds may be at high levels.

Fertilisers should be selected that have low levels of contaminants such as heavy metals (cadmium, lead or mercury). High levels in fertilisers may lead to accumulation in the soil or uptake by crops in excess of maximum levels (for information regarding maximum levels, see
the Food Standards Code www.foodstandards.gov.au).

Nutrient Losses

Nutrients may be lost from the production area by:

- leaching past the root zone and into groundwater, during the season with irrigation water or after harvest form bare paddocks (if it rains)
- moving as dissolved nutrients or attached to soil sediments and within organic particles in surface water run-off,
- attached to wind-eroded soil particles,
- volatilisation into the atmosphere.

Not only are these nutrients lost for crop production and a waste of money, such losses may have downstream or off-farm impacts on the environment. The nutrients most at risk of causing off-farm impacts are:

- nitrogen, a highly soluble element that is easily leached from the soil profile, dissolved in run-off water or volatilised into the atmosphere, and
- phosphorus, which binds strongly to soil particles and so can be lost by soil erosion through surface water run-off and wind. Leaching may occur in light soils.

Objective methods such as nutrient budgeting and crop monitoring (visual assessments, plant and soil testing) combined with yield / quality / crop health data provide the basis for good nutrition management. This means just enough nutrients are applied in the appropriate form and time to ensure good crop growth and health without providing excess nutrients which may be lost off farm or compromise crop heath and quality.

Special attention has to be paid to P and N losses when effluent or waste water are used. Site risk assessments are an essential part of nutrient management planning in these circumstances.

The following approach will assist in achieving environmentally responsible nutrient management:

Monitoring

- **Indicator 1** - average concentration of nitrogen & phosphorus (K in surface and groundwater. This indicator provides information on the magnitude of the problem and changes over time.

- **Indicator 2** - intensity of fertiliser use, including organic and recycled materials, on agricultural soils to monitor potential pressures on water resources from run-off and leaching. Showing the spatial distribution of fertiliser / manure/effluent use. This indicator can help targeting problem areas by introducing measures that achieve a balance between the application of nutrients and crop uptake.

- **Indicator 3** – Crop nutrient budgets based on crop uptake and removal figures combined with soil and plant analyses to estimate the exact quantity of fertiliser needed by plants. This indicator can assist in preventing excess nutrients to leach to surface or groundwater at an on-farm level.

Indicator 3 is not straightforward. The quantity of nutrient required and the risk of leaching vary with agro-ecosystem conditions (e.g. soil type & condition – structure microbial activity, slope, distance form waterways, climate), cropping patterns & practices, and season. They all influence the actual nutrient uptake of crops as well as N-inputs through precipitation, the mineralisation of soil organic matter (humus, crop debris, manure etc) and losses through denitrification and volatilisation. Advanced methods and models of nutrient management are taking agro-ecosystem conditions into account.

In the US, leaching from manures has been a major driver of developing assessment methods and recommendations P loss risk management. There, a Phosphorus Site Index (PSI) has been developed to evaluate the relative risk of P loss to water from a paddock based on site characteristics that affect P transport, the type of P source applied, and soil and crop management practices. Organic and mineral P inputs may be weighed differently depending on their potential to release P to runoff and leaching. P solubility from fertilisers and organic sources has been found to differ widely. The water extractable content or Mehlich 3 P saturation ratio (PSR) provides a good soil test based estimate of potential P loss through leaching. The P site index recommends the use of a 'phosphorus source coefficient' (PSC) to characterise the relative mobility and plant availability of P from different organic sources. It is a quantitative laboratory estimate of the relative solubility and bioavailability for soils amended with organic P sources, compared to soils amended with fertiliser P.

A complete P pollution risk assessments should comprise:

- Site risk assessment (erosion risk, soil type & condition, climate, soil, crop, irrigation management, distance to waterways etc) plus
  - P source coefficient
  - Relevant soil tests for plant available / leachable P
  - Adsorption and desorption curves to assess adsorption capacity status
  - Consideration of crop uptake and removal figures (crop nutrient budget)

General Nutrition Information

Fertiliser Industry Federation of Australia (2001) Cracking the nutrient code. www.fifa.asn.au Provides information on benefits and risks of fertiliser use, responsible management practices, monitoring tools and accreditation programs

Nutrient management decision guide[1]

Do you know what type and amount of nutrients your crop needs and when they are required?

No

Find out crop nutrient uptake and removal figures from government/industry publications, agronomist, consultant or fertiliser representative.

Yes

Do you know nutrient levels and fertility conditions in the crop rootzone?

- Major and minor nutrients (trace elements)
- Available soil nitrogen
- Soil pH, salinity, sodicity
- Organic matter inc crop residues
- Irrigation water quality
- Soil structure,
- Soil texture
- rooting zone depth
- soil microbial indicators

No

Undertake soil and water tests or assessments as required

Yes

Do you know the risk of nutrient losses or poor availability to the crop due to:

- Potential leaching of nutrients pass the rootzone
- Potential losses of nutrients in surface run-off water (or by wind)
- Volatilisation (losses to air)
- Nutrient fixing (clay minerals, microbes)
- Poor or unhealthy root system
- Poor irrigation water quality

No

Assess the risk and costs of nutrient losses or poor uptake conditions

Yes

Do you have information of the mode of action of different fertilisers in regards to:

- Nutrient concentration
- Nutrient form or formulation
- Salt index or acidification potential
- Potential losses, fixing or nutrient interactions

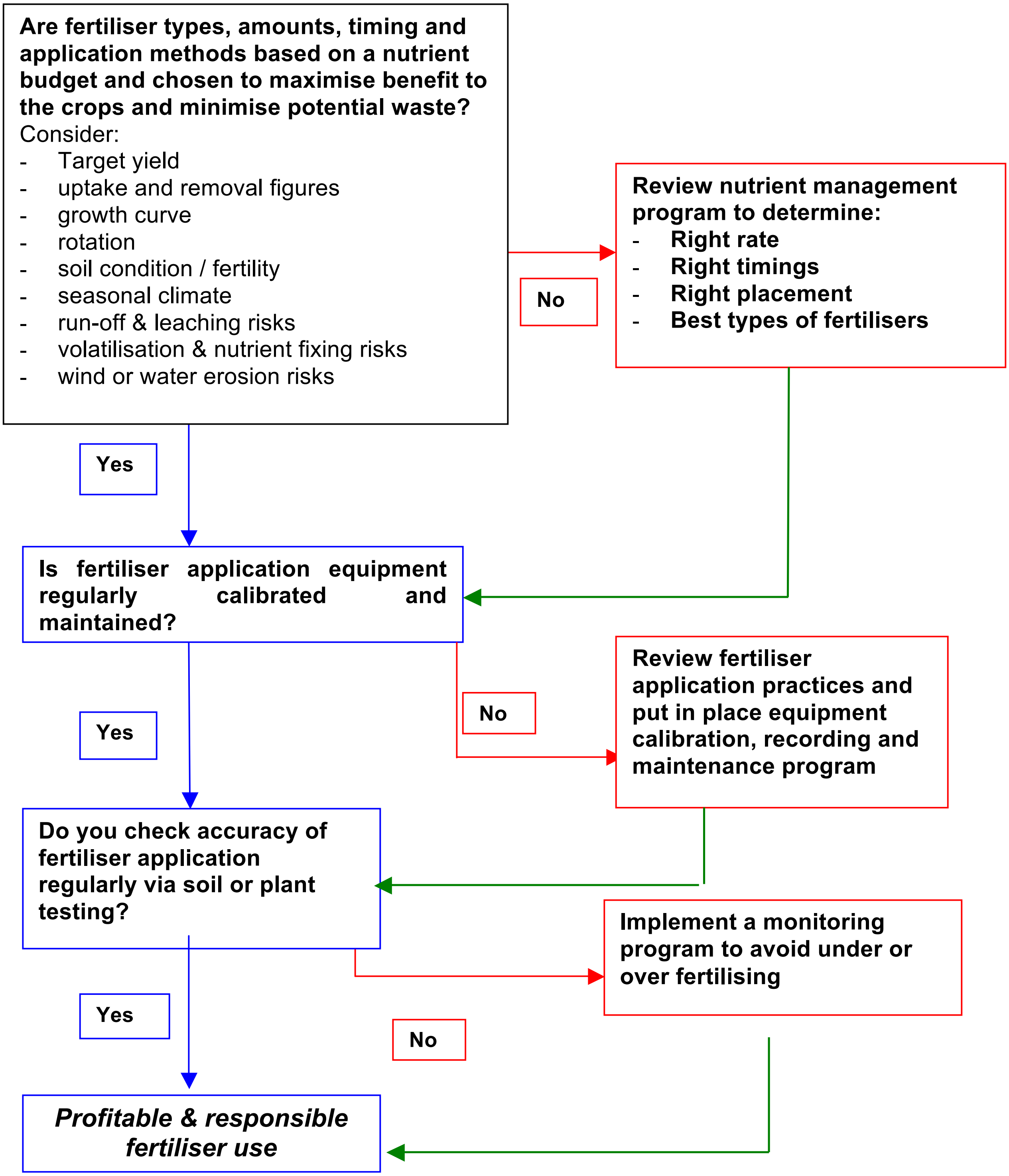
No

Obtain information from supplier, agronomist, consultant or internet etc

Develop paddock nutrient management programs that meet crop needs; try to plan for a several year rotation; consider the value of soil improvements; consider irrigation strategies and water quality.
Obtain quality planting material (variety, health, age etc) to get good establishment.
Try to minimising potential impacts on the environment.
Monitor crop growth and consider soil nitrogen, and plant testing during crop growth to adjust nutrient status.

1

Fertiliser application decision guide[2]



[2] This and previous diagram was adapted from: Guidelines for Environmental Assurance in Australian Horticulture, published by Horticulture Australia Limited

Some hints

Applying the most suitable types of fertilisers and soil conditioners (e.g. manures) at the right rate and frequency/timing is important. Application equipment must be set up correctly. Some general rules should be followed

- Avoid applying fertiliser to saturated soil or when heavy rain is forecasted.
- Avoid applying fertiliser during extended drought
- Use contour drains to minimise run-off on slopes
- Monitor soil moisture to avoid irrigation water to run past the root zone and carry nutrients with it
- Maintain a vegetation cover through typically rainy periods to take up nitrogen that may otherwise be leached
- Use stubble retention to avoid soil and nutrient loss during windy & dry periods
- Nitrogen should **not** be applied upfront in large amounts, if volatilisation or leaching may occur
- Select the most suitable fertiliser type, depending on the speed of availability of nutrients in relation to crop demand, acidity, alkalinity or salinity (salt index) of fertiliser
- Foliar application is a useful method for applying targeted amounts of micronutrients as a supplement to correct imbalances, or if rootzone / weather conditions affect root uptake
- Be careful not to apply fertiliser to non-crop areas or adjacent to waterways. Take steps to prevent contamination of water sources from pump backflow during fertigation

Fertiliser application records

Suggested headings in fertiliser records are:

- block or paddock identification,
- application dates,
- the type of fertiliser used including the trade name, type of fertiliser and concentration of nutrients,
- amount of fertiliser applied per hectare (weight or volume),
- the amount of nutrients in kg/ha applied with the fertiliser
- method of application
- name of the operator applying the fertiliser.

A copy of he nutrient budget, soil test results for the paddock and plant sap tests for the crop should be filed with fertiliser records.

Machinery calibration and maintenance

Keep maintenance and calibration records for fertiliser application equipment.

- equipment/machinery name,
- date on which maintenance was performed,
- work undertaken, and
- signature or initials of the person who performed the maintenance, or an appropriate invoice.

A tractor auto steering system will allow precise applications without overlaps and may safe fertiliser costs. It will increase use of the paddock are by 5-10% for the same reason.