Nutrient Management Plan for the Banana Industry

(of north Queensland)

Background

This Nutrient Management Plan is designed to complement the detailed publication, Banana Best Management Practices Environmental Guidelines available from the ABGC website. The Plan is based on the best available research, grower expertise and expert opinion. It aims to provide the basis for the industry to continue the considerable improvements in nutrient management, particularly nitrogen application rates, by the industry over the last 25 years.

It should be a dynamic document that is reviewed periodically when new research and information becomes available.

Acknowledgements

Valuable feedback and comments were received from Michelle McKinlay, Robert Mayers, Sarah Simpson, Dale Bennett (ABGC); Tegan Kukulies and Stewart Lindsay (QDAF); Matt Weinert (NSW DPI) and Phil Moody (QDES) – thank you for your guidance.

Prepared for the Australian Banana Growers' Council

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Introduction

This Nutrient Management Plan is to help growers efficiently manage the nutrient supply to banana plants. Increased understanding of nutrient management and increased confidence to query agronomic advice will help you do this. You should aim to use the minimum amount of fertiliser required for the productivity you need for your business. Benefits are:

- reduced production costs
- minimised loss of nutrients (particularly nitrogen and phosphorus)
- minimised contamination of streams, groundwater and the GBR
- reduced impact of excess fertiliser on soil health.
- reduced pressure from some diseases and pests.

Nutrient Management Plans are 'living' documents and need to be updated as your management practices change or new information on nutrient management (such as new fertiliser forms) becomes available.

Good fertiliser management does not reduce farm productivity.

Nutrients are mainly applied as fertilisers but other sources may be important. These include mulches and products like chicken manure. Nitrogen is also released from the soil organic matter pool during intensive cultivation such as at planting, and during any fallow period. Plants do not 'care' where the nutrients are sourced from. It is only the amount and availability that control plant growth and fruit production.

Offsite impacts of farming

The greatest risks to water quality in the Great Barrier Reef are from nitrogen discharge and fine sediment discharge, and the greatest sources of these pollutants are from agriculture. Excessive use of phosphorus is also important as it is mostly transported off-farm in fine sediment. The water quality impacts of off-farm nutrient exports include the triggering of Crown of Thorns starfish outbreaks, algal blooms and reduced light for seagrass and coral. Many banana farmers enjoy fishing, and reducing the environmental impacts on the reef will help retain good fish stock.

These impacts have resulted in increased scrutiny of farm management, particularly in the sugar industry and now for bananas. The industry has made large improvements in the efficient use of nitrogen fertiliser. Good productivity is being achieved with nitrogen fertiliser rates that are approximately 55% of the rates used in 1995. Apart from reducing production costs and likely improving overall soil health, this change is important for environmental reasons and community perceptions of the industry.

A recent soil phosphorus project assessed the current available phosphorus status of banana blocks and concluded that many blocks needed nil or little phosphorus for optimum productivity. Reducing phosphorus fertiliser inputs in line with recommendations will not only result in lower production costs, but will also reduce environmental risk.

Generally, the more nutrient that is applied, the more that is likely to be lost from the block.

Production area

The main banana production area is on the wet tropical coast with high rainfall (average of 1,850 mm per year in the Wet Tropics region). However, 70% of the rain falls in December-April which coincides with the period of greatest crop growth, and therefore nutrient demands of the plants. This environment is challenging for efficient nutrient management due to hot, wet soil conditions and the chance of heavy rainfall at any time of the year.

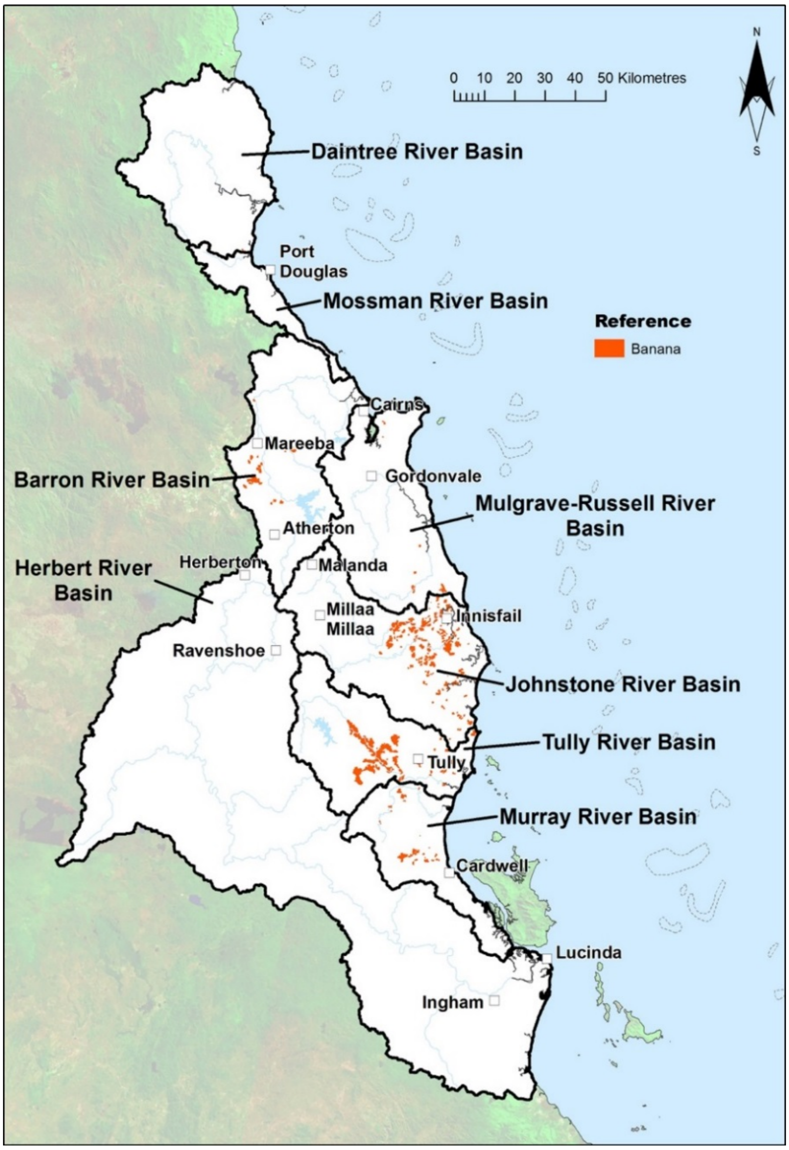

Figure 1. Banana production areas in the Wet Tropics region
Source: Spatial Information Unit, DNRM, Toowoomba, June 2016

This farm nutrient management plan has five components:

1. Understanding soils, nutrient processes and loss pathways;
2. Setting targets for nutrient application to achieve desired productivity;
3. Undertaking soil testing to guide nutrient management;
4. Using leaf testing to guide nutrient management;
5. Keeping records for efficient nutrient management and economic analysis.

A farm nutrient management plan is a 'living' document. It should be continually updated as more information on banana nutrition and best management practices becomes available, prompting you to make changes in your production system.

1. Soils, nutrient processes and loss pathways

Soils are important.

'Despite all our achievements, we owe our existence to a 150 mm layer of topsoil and the fact that it rains'. (Anon).

Bananas have most roots in the surface 40 cm and like all agricultural crops, depend upon soil for:

- Water and air;
- Nutrients;
- Physical support;
- Biological activity – both good (nutrient cycling; disease suppressiveness) and bad (soil-borne diseases and pathogens);
- Absence of constraints to crop growth (e.g., excessive soil acidity, salinity, toxic contaminants).

The soil properties that control these important functions are:

- pH – controls relative availability of nutrients;
- Structure – arrangement of soil particles and pores in soil that determines soil drainage and aeration;
- Texture – sand, silt and clay content that determines soil water holding capacity and nutrient holding capacity;
- Mineralogy – parent material that the soil is formed on which determines the texture and type of clay minerals in the soil;
- Organic matter – a critical component that influences many soil physical, chemical and biological functions;
- Soil biology– millions of species of microorganisms and other biota such as earthworms.

Plant growth and block production are controlled by the most limiting factor in that block. The law of limiting factors states that crop growth and yield potential will be limited by the factor that is in the shortest supply. This factor may be seasonal such as temperature or solar radiation, but may also be a soil constraint.

In the example shown in Fig. 2, it is nitrogen that is limiting growth. This means that nitrogen deficiency needs to be fixed before other factors are considered. For example, extra phosphorus will not increase productivity.

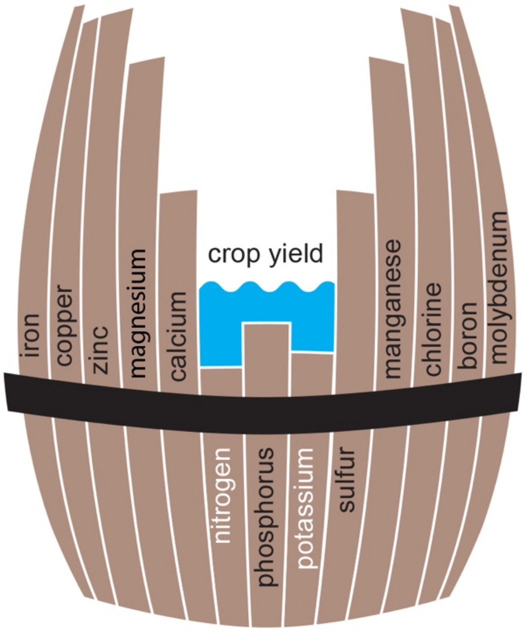

Fig. 2. Representation of the effect of limiting factors on plant yield.
Image courtesy of NSW DPI.

1.1 Soil quality and soil health

Soil quality and soil health are related concepts and can be defined as follows:

Soil quality – 'native' properties of the soil such as clay content, internal drainage, position in landscape, sodicity. These properties depend on soil formation factors such as parent material, climate, organisms and time.

Soil health - capacity of soil to sustain plant production and maintain or enhance water quality.

These definitions separate the 'native' soil properties (those that cannot be readily changed) from other properties of the whole soil which can be managed and improved as a basis for sustainable and productive agriculture (Fig. 3).

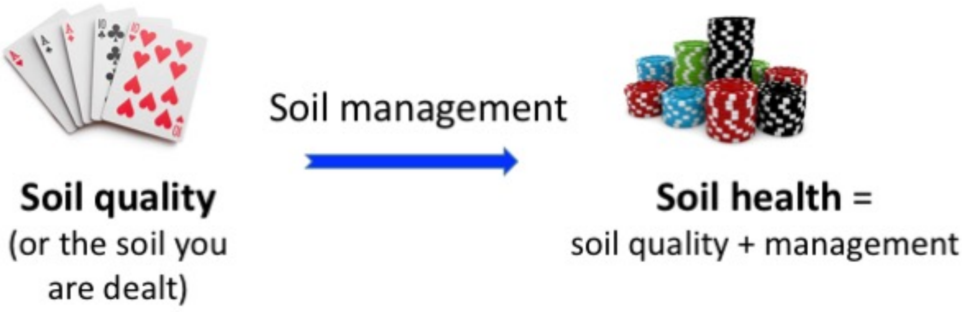

Fig. 3. Relationship between soil quality and soil health

1.2 Some important soil properties

Many soil properties can affect block productivity. The main ones for banana production are:

- Clay content – clay-sizes particles (<0.002 mm) have huge surface area compared to sand-sized particles (<2mm). Nutrient holding capacity and water holding capacity increase with increasing clay content.
- pH – controls the availability of all nutrients to bananas, directly or indirectly.
- Available phosphorus. The Colwell P test is the most commonly used soil test in Australia and is determined by all major soil laboratories. Guidelines for P management for bananas have been developed in a recent project (https://abgc.org.au/phosphorus-rd/).
- Exchangeable potassium, calcium, magnesium and cation exchange capacity (CEC). CEC is a measure of the ability of the soil to retain nutrient cations such as potassium, calcium and magnesium, and is determined by clay content/type and soil organic matter content.

1.3 Loss pathways of nutrients

Nutrients are distributed throughout the banana root zone and can be lost from the block to the environment by three pathways (Fig. 4).

- Water movement – runoff and deep drainage. Large quantities of water move through and over soils in the Wet Tropics.
  - Runoff
    In the Innisfail-Tully area, runoff from blocks is typically 500-900 mm/year and can erode productive topsoil.
  - Deep drainage
    Drainage below the roots typically ranges from 800-1,400 mm/year (Innisfail-Tully area). It is a major loss pathway for nitrogen in the form of nitrate. Nitrogen from all nitrogen fertilisers is rapidly transformed to nitrate under normal conditions by

specialised soil bacteria.

- Erosion
  - Loss of the most fertile topsoil. Erosion rates may be many times higher than the rate of soil formation. Losses of up to 11 **tonnes topsoil**/ha was measured on a site with low slope at South Johnstone, whereas soil formation rates are approximately 5 **kg**/ha/year. Controlling erosion is a sustainability challenge for the industry.
  - Main loss pathway of phosphorus which is attached to soil particle surfaces;
  - Can spread soil borne pests and diseases (e.g. TR4).

- Gaseous loss of N by the processes of ammonia volatilisation and denitrification of nitrate-N.

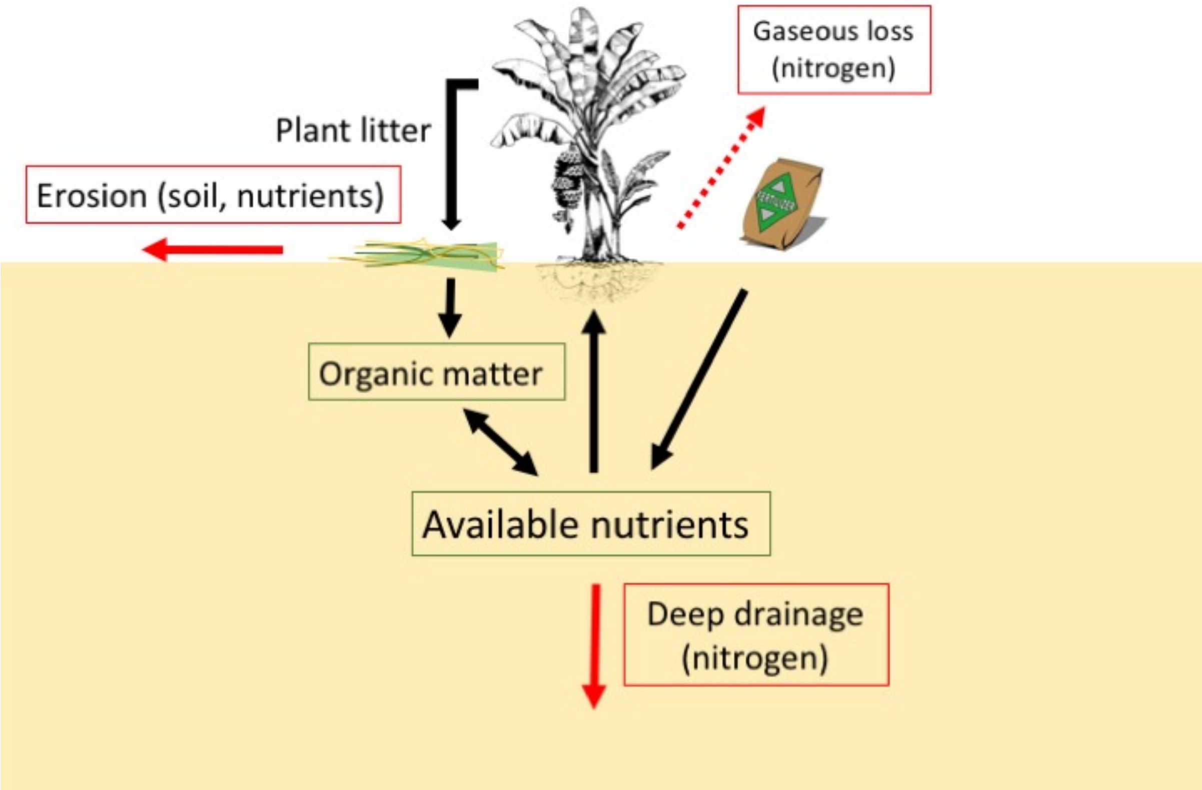

Fig. 4. Summary of nutrient movement and transformations in soils.

1.4 Soil types used for banana production

A wide range of soils are used for growing bananas in north Queensland (Table 1). This needs to be taken into account by management practices because the properties of different soils will influence effective nutrient and irrigation management (Table 2).

Table 1. Major soils used for banana production in north Queensland.

Soil series	Area (ha)	% of banana area	Soil profile class	Soil description[1]	Drainage
Coom	320	3	Hydrosol	Uniform or increasing clay content with depth, mottled B horizons	Poor
Eubenangee	370	3	Dermosol, Ferrosol	Red structured soils on basalt, with increasing clay with depth	Good
Galmara	270	2	Dermosol, Ferrosol	Deep red soils, with increasing clay with depth, on low hills	Good
Innisfail	1,770	15	Dermosol	Structured brown or red soils with uniform or increasing clay content with depth	Good
Liverpool-Tully	760	6	Tenosol-Rudosol	Fine sandy loam or loam soils on flood plains	Medium-good
Mossman	320	3	Dermosol	Structured soils, with uniform or increasing clay content with depth	Good
Mundoo	580	5	Dermosol-Ferrosol	Red structured soils, with increasing clay with depth, on alluvial fans from basalt	Good
Pin Gin	1,730	15	Dermosol-Ferrosol	Red structured soils, with increasing clay with depth, formed on basic volcanics	Good
Thorpe	540	5	Kandosol	Yellow unstructured soils, with uniform or increasing clay with depth, formed on alluvial fans from granite	Good
Tolga	1280	11	Dermosol-Ferrosol	Deep, red, structured, uniform soils on gently sloping rises of basalt	Good
Tully	1,640	14	Dermosol-Ferrosol	Bright yellowish, silty clay loam to silty medium clay, with uniform or increasing clay with depth	Medium-good
Utchee	260	2	Kandosol	Clay content uniform or increasing with depth, with deeper red horizon over decomposed granitic rock	Good
Virgil	370	3	Kandosol	Unstructured red sandy clay loam to clay soil on inactive terraces of large streams	Good
Walkamin	260	2	Dermosol-Ferrosol	Moderately deep to deep mottled nodular yellow-brown structured clays	Moderate

[1]Data supplied by DNRM

Table 2. Typical soil properties (0-10 cm) for some common banana soils.

	Clay (%)	Coarse sand (%)	CEC[1]
Soil series			
Thorpe	12	49	4.7, moderate
Pin Gin	50	9	3.8, moderate
Tully	42	3	11, good
Utchee	29	54	2.5, low

[1]CEC – cation exchange capacity (cmol/kg or m.equiv./100g).

Maps and information about the soils are available online at no charge from the Queensland Globe (https://qldglobe.information.qld.gov.au/).

2. Targets for nutrient application

Applying rates of nutrient that are 'about right' is an excellent place to start a nutrient management program. Efficient nutrient management **will not** reduce productivity, and it will reduce production costs and help maintain soil health. Pests and diseases may greatly reduce nutrient uptake and this cannot be corrected with extra fertiliser.

The effectiveness of the fertiliser program can be monitored by:

1. Productivity - are you achieving the production that you need to remain viable?
2. Soil analysis
3. Plant analysis

Fertilisers and amendments (such as liming products) can be divided into two groups:
- Regular application - nitrogen and potassium should be applied regularly throughout the year for efficient plant uptake
- Occasional application such as at planting or every few years. This includes phosphorus and liming products (lime, dolomite and lime/magnesium blends).

Efficient fertigation systems may allow rates to be reduced by up to 25%, compared to infrequent application of solid fertiliser. In any case, soil and plant analyses are important monitoring tools. Additional information about soil and fertiliser management is available from the Banana BMP (https://abgc.org.au/projects-resources/best-management-practices-bmp/)

4 R. The international 4R Nutrient Stewardship concept for fertiliser best management promotes applying:
- the **right** source of plant nutrients (or product)
- at the **right** rate
- at the **right** time and
- in the **right** place

http://www.nutrientstewardship.com/4rs/

2.1 Nitrogen (N)

Nitrogen fertiliser usage by the industry has reduced greatly over the last 20 years. The most recent survey reported that the average industry usage is 290 kg nitrogen/ha/year (Sing 2012). Nearly half the production area received 251-300 kg nitrogen/ha/year, while 21% received greater than 351 kg nitrogen/ha/year.

Bananas can be grown profitability with lower rates of fertiliser nitrogen. Detailed research at South Johnstone Research Station showed that productive ratoon crops (ratoons 1, 2 and 3) could be grown with 200 kg N/ha/year. The nitrogen was fertigated every fortnight on ratoon crops grown with about average annual rainfall.

However, growers on commercial farms are subject to different pressures to those at an intensively managed experimental site. The recommended target for this nutrient management plan is 250-350 kg nitrogen/ha/year for ratoons. This range in N rates is to allow for the different production systems. Growers should regularly monitor the effectiveness of their N fertiliser inputs by leaf testing, and make adjustments to ensure that the crop is able to recover the maximum amount of fertiliser N. Nitrogen should be applied at intervals of less than 3 weeks to ensure a constant supply to the plant.

Fertiliser application rates – summer vs winter
A refinement of efficient fertiliser management is to reduce application rates during slower growth periods in winter. This will be more important in the cooler growing areas such as New South Wales and the Atherton Tablelands.

More information for NSW is available:
http://www.dpi.nsw.gov.au/agriculture/horticulture/tropical/growing-bananas/sub-tropical-banana-nutrition

2.1.1 Plant crops

Conventional ground preparation (full cultivation) releases a large amount of nitrogen (as much as 260 kg of nitrate-nitrogen/ha in the surface 40 cm) from organic matter. This N is available to the plant, but can also be lost by pathways such as:

- deep drainage
- gaseous losses
- incorporation back into soil organic matter by soil microorganisms.

The amount of available nitrogen in the soil can be measured before planting with a soil nitrate-N test of the 0-20 cm soil depth. In the early stage of a plant crop, there is only a small root system to take up nutrients, so high rates are not needed (Fig. 5). The slow growth of plants in the first 3 months is clearly shown in Figure 6.

 

Fig. 5. Developing plants have a lower nitrogen requirement than larger plants at full growth rate.

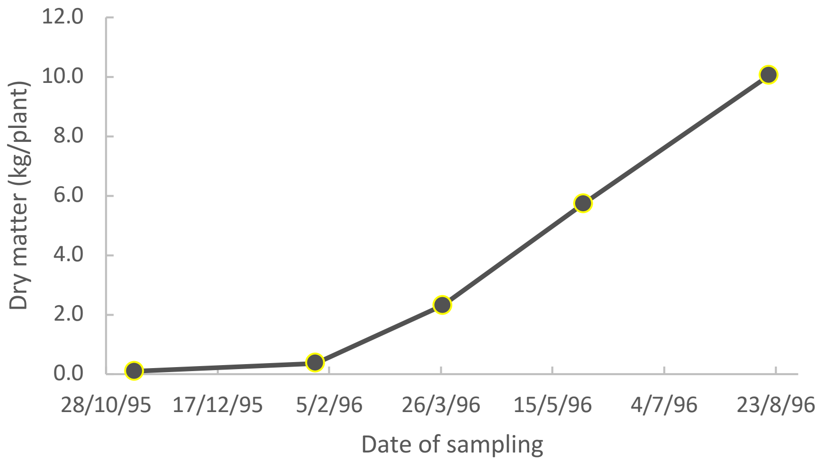

Fig. 6. Growth of plants (shoots and corm) for a plant crop at South Johnstone in 1995-96.

Table 3. Guidelines for nitrogen fertiliser rates for a <u>plant</u> crop based on nitrate concentrations (0-20 cm).

Soil nitrate-N (mg/kg) in 0-20 cm	**Rate of nitrogen fertiliser (kg nitrogen/ha/year)**
<20	125-175
20-40	100-150
>40	75-125*

* Delay application of nitrogen fertiliser for at least 1 month after planting.

2.1.2 Ratoon crops

A target rate for ratoon crops is 250-350 kg/ha/year for crops that are regularly fertilised with nitrogen. Different rates may be needed for individual farm situations and should be monitored with leaf tests.

Nitrogen recommendation – ratoon crops
250-350 kg/ha/year applied in split applications at intervals of less than 3 weeks.

2.2 Phosphorus

Bananas have a low requirement for phosphorus and fertiliser rates should be adjusted according to the soil test result (Table 4).

- Research at South Johnstone measured a critical Colwell-P soil test level of 45 mg/kg for a highly phosphorus-fixing red volcanic Ferrosol soil. The phosphorus-fixing ability of a soil can be measured using the routine Phosphorus Buffer Index (PBI) soil test.
- Use the Colwell-P soil test to decide appropriate P fertiliser rates (Table 4).
- Many banana blocks in north Queensland need little or no phosphorus fertiliser (Armour and Lait 2017) because they already have high Colwell-P soil test values. This is the result of a build up from years of phosphorus fertiliser application.
- Trends over time are an important monitoring tool for your fertiliser program. Check if your Colwell-P soil P test levels are steady, or increasing/decreasing. Excessive application over time will be revealed in soil tests, as shown by monitoring at South Johnstone (Fig. 7).
- Excessive concentrations of phosphorus in the soil may reduce the availability of other nutrients such as zinc, iron and copper.

Avoid applications of phosphorus in the wet season because of the risk of loss in runoff.

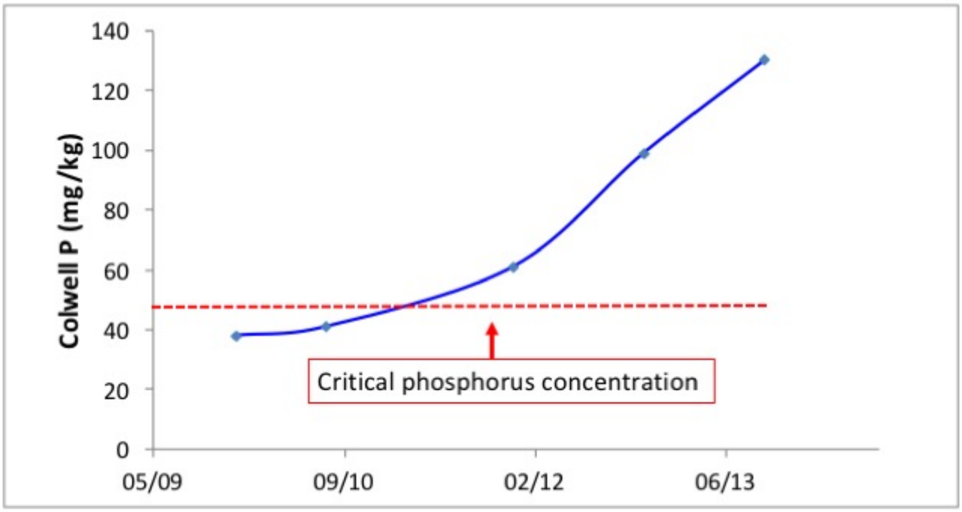

Fig. 7. Rapidly increasing Colwell-P soil test levels in 0-10 cm from high phosphorus applications at South Johnstone (total fertiliser P application of 110 kg phosphorus/ha).

Table 4 Guidelines for phosphorus application rates based on Colwell-P levels (0-20 cm).

Category	Colwell-P (mg/kg) in 0-20 cm	Phosphorus fertiliser application rates
Very low	<20*	Apply 70 kg phosphorus/ha for the plant crop, then 20-60 kg/ha as a maintenance rate for each ratoon crop. Check soil test annually and adjust fertiliser rate if needed.
Low	20-45	
Medium	45-75	Apply phosphorus equivalent to crop removal of 20 kg/ha for the plant crop, then 20 kg/ha/crop as a maintenance rate for ratoons. Check soil test annually and adjust fertiliser rate if needed.
High	75-100	Apply phosphorus equivalent to crop removal of 20 kg/ha at planting. Do not apply any phosphours fertiliser to ratoon crops until the annual soil test shows that Colwell-P has declined to less than 75 mg/kg.
Very high	>100	Do not apply any phosphorus fertiliser to plant or ratoon crops until the annual soil test shows that Colwell-P has declined to less than 75 mg/kg

*These very low concentrations are found in only 5% of banana blocks in the Wet Tropics.

2.3 Cations – potassium, calcium and magnesium

It is difficult to set targets because of the range of cation exchange capacities (CEC) in soils. For example, low CEC soils will never hold as much potassium (K) as a high CEC soil, in the same way that a 5 L bucket will not hold 10 L! (Fig. 8). A good management practice is to apply the suggested rate of potassium (in particular) and monitor trends in soil potassium tests over time.

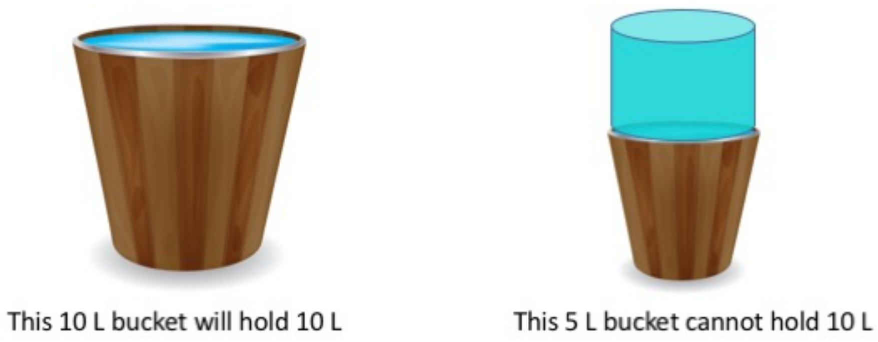

Fig. 8. Representation of the cation exchange capacity of a soil and its ability to retain cations such as potassium.

Cation ratios
Desirable ratios of potassium to calcium, calcium to magnesium and others are often quoted by agronomists and advisors. However, these ratios are not universally supported by soil scientists. Plants have a good ability to adapt to a range of ratios of these cations. Restricted growth only occurs at extreme ratios that are rarely found in agricultural soils.

Lime products, when used at the rate of tonnes/ha, supply large amounts of calcium as well as helping manage soil acidity. It is advisable to use lime blends (such as dolomitic limestones) that contain some magnesium to maintain a supply of magnesium to bananas when the soil is so 'loaded' with calcium.

2.3.1 Potassium

Bananas will take up large amounts of potassium and more than they need for good production. Relatively large amounts of potassium are required by bananas during their growth cycle and K should be applied regularly, rather than in large occasional doses.

The guidelines in Table 5 are based on limited scientific research in Australia and globally – soil and leaf levels are important for monitoring your fertiliser program.

Table 5. Guidelines for potassium fertiliser based on soil exchangeable potassium levels (0-20 cm).

Rating	Exch. potassium (cmol/kg) in 0-20 cm	Rate of potassium fertiliser (kg potassium/ha)
Low	< 0.2	450
Medium	0.2 – 0.5	400
High	0.5 – 1	350

2.3.2 Calcium

Calcium is normally only applied in liming products to maintain a suitable pH (5.5-6.0). Liming products include lime, dolomite and other blends of lime and magnesium products (dolomite and magnesium oxide).

2.3.3 Magnesium

Magnesium is a macro-nutrient and plants need a good supply of it. Magnesium should be included in liming products (blends with 3-5% magnesium are available) as a convenient method of application. This should avoid reduced availability of magnesium from a large dose of calcium in lime, as well as the frequent applications of potassium.

3. Soil testing to guide nutrient management

3.1 Soil analysis

Soil analysis is a guide to the fertility of your soil to plan fertiliser application to a plant block and to monitor ratoon blocks. Soil tests estimate the plant-available nutrients in the soil. Many methods of soil analysis are available. However, some soil test methods from overseas are not applicable to Australian soils and give results that cannot be interpreted.

Soil sampling has three key steps, and all are critical to obtaining reliable results.

3.1.1 Sample collection.

It is essential that a representative soil sample is taken. If it is apparent from field observations or soil maps that there is more than one soil type in a block, then a separate representative sample should be taken from each soil type. Samples should be taken from the same local area to allow for easy monitoring of soil tests over time. A GPS reading of each sample area will simplify this.

The recommended sampling depth for banana crops is 0-20 cm and samples should be taken in the irrigated zone in the middle of the row. Detailed guides are available on the web and examples are:

http://www.ehp.qld.gov.au/assets/documents/agriculture/sustainable-farming/rwq-soil-sampling-method.pdf
http://www.incitecpivotfertilisers.com.au/en/Soil%20,-a-,%20Plant%20Tests/~/media/Files/IPL%20pdfs/Horticulture%20Soil%20Sampling%20Procedure.ashx

3.1.2 Laboratory analysis.

Use a laboratory certified by the Australasian Soil and Plant Analysis Council (ASPAC) or accredited by the National Association of Testing Agencies (NATA). This accreditation indicates that the laboratory practises an appropriate quality assurance system to minimise errors. The laboratory should use soil test methods that have been calibrated with banana growth. This means that the numbers on the analytical report can be interpreted for your local conditions and soils. The Colwell-P soil test is particularly important as it is the only soil phosphorus test that has some critical calibration data for bananas.

Biosecurity restrictions apply to soil (and leaf samples) sent to Queensland and NSW laboratories, but not to Victorian laboratories. Check with Biosecurity Queensland for quarantine requirements.

3.1.3 Interpretation of the results by experienced agronomists/advisors.

Interpretation of soil tests requires specialised knowledge about the crop and local conditions to determine if:

- the concentrations are deficient, satisfactory or surplus
- modification of the nutrient management program is required

Advisors should be able to demonstrate their competency by accreditation or training. An example of accreditation is the Fertcare Accredited Advisors program (http://www.fertilizer.org.au/Fertcare/Trusted-Advisors/Trusted-Nutrient-Advice-For-Farmers).

3.2 Desirable ranges for important soil tests

Important soil tests are pH, available P, and the nutrient cations of potassium, calcium and magnesium. Surface soil samples (0-20 cm) should be tested annually and a deeper sample (20-40 cm) every 3 years. The deeper sample is necessary to monitor sub-soil pH and nutrient status. Sometimes subsoil acidification can occur even where regular liming of the surface soil is practised. If left unamended, sub-soil acidity can severely limit root growth and nutrient uptake.

3.2.1 pH

pH is important because it controls the availability of many nutrients. Toxicity of manganese and/or aluminium, or deficiency of calcium may reduce crop growth at very low (or acid) pH (1:5 water) values less than 5.0.

The optimum pH (1:5 water) range has been reported as 5.5 – 6.0 (Incitec Ltd), but good production can be achieved with values as low as 5.0. Ensure that your soil test has pH measured in water (and not calcium chloride which gives a lower soil pH value). Decreasing soil pH over time (or increasing acidity) can indicate that there is a high level of nitrogen being leached out of the root zone. Early detection of subsoil acidification (20-40 cm) is essential because it is a very difficult and expensive problem to correct.

3.2.2 Nitrogen

Nitrate–nitrogen at planting to modify fertiliser program in early stages of plant crop. Soil testing for nitrate-nitrogen is only useful if samples are taken as close as possible to planting (1-2 weeks). This will indicate the availability of soil nitrogen released during ground preparation. Nitrogen fertiliser application for the plant crop can be reduced if there is high nitrate-N in the soil.

There are approximately 6 tonnes of total nitrogen/ha in the surface 0.4 m of soil, but most is not available to the bananas because it is in organic form. Plant available forms of nitrogen are nitrate-nitrogen and ammonium-nitrogen. Soil nitrate concentrations change rapidly over time and this limits the usefulness of soil nitrate tests. The variability in the soil nitrate concentrations is due to how and when fertiliser was applied, plant uptake, losses and other soil processes.

3.2.3 Phosphorus

Colwell-P is the most commonly used soil phosphorus test in Australia and is a reliable guide to available phosphorus. Phosphorus fertiliser application should be guided by the Colwell-P result (Table 4).

Trends in Colwell-P concentrations over time are a critical guide for informing best phosphorus management. For example, excessive P application compared to plant uptake is clearly demonstrated by trends in Colwell-P over time in Fig. 7.

3.2.4 Potassium

The recommended critical soil test concentration for exchangeable potassium is 0.5 cmol/kg (or 0.5 m.equiv./100 g, in older terminology). Note that this concentration may not be achievable in very sandy soils because of their very low ability for retaining nutrient cations. Use the recommended rate of potassium and check trends in your soil test and leaf test results.

3.2.5 Micro-nutrients (trace elements)

There is very little information for bananas on desirable soil concentrations for the micro-nutrients: copper, zinc, manganese, iron, boron and molybdenum. However, deficiencies of these nutrients are not common in the banana cropping system.

4. Leaf testing to guide nutrient management

4.1 Leaf analysis

Leaf testing will monitor the effectiveness of your nutrient management and farm soil fertility. As for soil sampling, leaf sampling has three key steps, and all are critical to obtaining reliable results

4.1.1 Sample collection

The diagnostic leaf is the third fully expanded leaf and should be collected when plants are approximately half-grown (Fig. 9). However, samples may be collected about a month earlier or as late as bunch emergence. To compare leaf test results from crop to crop, it is best to collect the same age plant at a similar time of year.

Detailed sampling guides are available on the web. For example:

http://www.incitecpivotfertilisers.com.au/en/Soil ,-a-, Plant Tests/~/media/Files/IPL pdfs/Plant Tissue Sampling Procedure1.ashx
http://www.dpi.nsw.gov.au/agriculture/horticulture/tropical/growing-bananas/sub-tropical-banana-nutrition

4.1.2 Laboratory analysis

Use a laboratory that is certified/accredited by ASPAC or NATA. This accreditation indicates that the laboratory practises an appropriate quality assurance system to minimise errors.

4.1.3 Interpretation of the results by experienced agronomists/advisors

Interpretation of leaf tests requires specialised knowledge about the crop and local conditions to determine if:

- the concentrations are deficient, satisfactory or surplus
- modification of the nutrient management program is required

Advisors should be able to demonstrate their competency by accreditation or training. An example of accreditation is the Fertcare Accredited Advisors program (http://www.fertilizer.org.au/Fertcare/Trusted-Advisors/Trusted-Nutrient-Advice-For-Farmers).

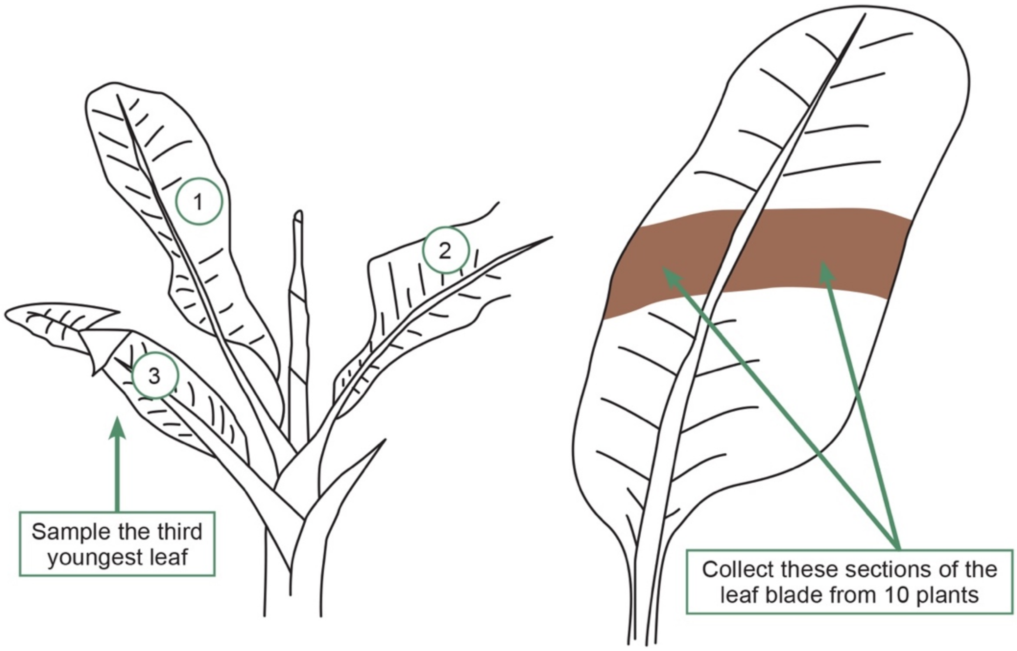

Fig. 9. How to collect leaf samples for analysis.
Image courtesy of NSW DPI.

4.2 Desirable ranges in the leaf nutrient concentrations

The ranges have been summarised from local research and international scientific literature (Table 6).

Table 6. Leaf concentrations of nitrogen, phosphorus and potassium (oven dry basis)

	Low	Adequate	Surplus
Nitrogen (%)	<2.8	2.8-3.5	>3.5
Phosphorus (%)	<0.19	0.19-0.22	>0.22
Potassium (%)	<3.2	3.2-4.8	>4.8
Calcium (%)		0.5-1.0	
Magnesium (%)		0.27-0.4	

Sources: Reuter and Robinson, 1997, Incitec Pivot; J. Armour unpublished data.

Symptoms of nutrient deficiencies are available from a range of sources including ‘Sub tropical banana production – matching nutrition requirements to growth demands’, available from: http://www.dpi.nsw.gov.au/agriculture/horticulture/tropical/growing-bananas/sub-tropical-banana-nutrition

5. Record keeping

Farm record keeping is an essential component of modern farming. It is needed for both auditing and productivity assessment over time to inform necessary changes to nutrient management.

Good records can:

- Check on effectiveness of nutrient management by monitoring trends in soil tests and leaf analyses over time.
    - What are the trends in the main soil analyses of soil pH, Colwell-P and potassium, calcium and magnesium over time?
    - Do these trends show that the fertiliser program needs adjustment?
- Show trends in productivity
    - Are the blocks producing as well as they should?

Records are only useful if they are used for management decisions. The industry's app, BetterBunch is available to help with record keeping: https://records.bmp.abgc.org.au/

More information about record keeping for all aspects of farm management is available from the Banana BMP available from ABGC.

5.1 Managing a fertiliser program

The fertiliser program may need to be modified after a check on block or farm productivity and assessment of soil and leaf analyses. The best time to review the fertiliser program is after annual soil test results are received. This is part of the cycle:

'Set - Run - Check - Modify' (Fig. 10).

- Set nutrient targets
- Run fertiliser program
- Check productivity and soil and leaf test results
- Modify fertiliser management, as needed, to suit your situation (e.g. application method, block productivity, soil type etc.)

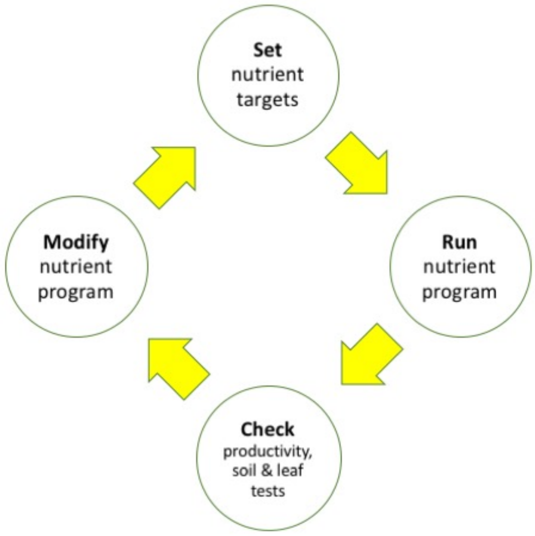

Fig. 10. A nutrient management cycle.

6.0 Summary of guidelines for rates of nitrogen, phosphorus and potassium fertiliser from soil testing

6.1 Nitrogen

Plant crop – guidelines for nitrogen fertiliser rates based on nitrate concentrations (0-20 cm).

Soil nitrate-N (mg/kg) in 0-20 cm	Rate of nitrogen fertiliser (kg N/ha/year)
<20	125-175
20-40	100-150
>40	75-125*

* Delay application of nitrogen fertiliser for approximately 1 month after planting

Ratoon crops

250-350 kg/ha/year applied at intervals of less than 3 weeks to ensure a constant supply to the plant

6.2 Phosphorus

Guidelines for phosphorus application rates based on Colwell P levels (0-20 cm)

Category	Colwell P (mg/kg) in 0-20 cm	Phosphorus fertiliser application rates
Very low	<20*	Apply 70 kg phosphorus/ha for the plant crop, then 20-60 kg/ha as a maintenance rate for each ratoon crop. Check soil test annually and adjust fertiliser rate if needed.
Low	20-45	
Medium	45-75	Apply phosphorus equivalent to crop removal of 20 kg/ha for the plant crop, then 20 kg/ha as a maintenance rate for ratoons. Check soil test annually and adjust fertiliser rate if needed.
High	75-100	Apply phosphorus equivalent to crop removal of 20 kg/ha at planting. Check soil test annually and adjust fertiliser rate if needed.
Very high	>100	Do not apply phosphorus. Check soil test before replanting.

*These very low concentrations are found in only 5% of banana blocks in the Wet Tropics.

6.3 Potassium

Guidelines for potassium fertiliser based on soil exchangeable potassium levels (0-20 cm).

Rating	Exch. potassium (cmol/kg) in 0-20 cm	Rate of potassium fertiliser (kg K/ha)
Very low - Low	< 0.2	450
Medium	0.2 – 0.5	400
High	0.5 – 1	350

7.0 Further reading

Armour, JD, Nelson, PN, Daniells, JW, Rasiah, V and Inman-Bamber, NG. (2013). Nitrogen leaching from the root zone of sugarcane and banana production in the humid tropics of Australia. Agriculture, Ecosystems and Environment. 180, 68-78.

Armour, JD and Lait, R. (2017). Final report on project RP158B, Optimum Soil Phosphorus for Banana Growing. (https://abgc.org.au/phosphorus-rd/)

King, N. (2016). Banana Best Management Practices. Environmental Guidelines for the Australian Banana Industry. https://abgc.org.au/projects-resources/best-management-practices-bmp/

Kopittke, PM and Menzies, NW. (2007). A review of the use of the basic cation saturation ratio and the “ideal” soil. Soil Science Society of America Journal. 71, 259-265.

Peverill, KI, Sparrow, LA and Reuter, DJ. (1999). Soil analysis: an interpretation manual. CSIRO Publishing.

Reuter, DJ and Robinson, JB. Editors (1997). Plant analysis: An interpretation manual. 2nd Edition. CSIRO Publishing, Collingwood, Australia.

Skocaj, DM, Telford, D, Hurney, AP and Schroeder, BL. (2018). Process for developing farm nutrient management plans in the wet tropics. Proc. Aust. Soc. Sugar Cane Technol., 40, 194-201.

Sing, N. (2012). Growers respond to farm practices survey. Australian Bananas Magazine. Midyear 2012.

Weinert, M and Simpson, M. 2016. Sub tropical banana nutrition – matching nutrition requirements to growth demands. NSW Department of Primary Industries. http://www.dpi.nsw.gov.au/agriculture/horticulture/tropical/growing-bananas/sub-tropical-banana-nutrition