Food for Fruit – Nutrition management in mangoes

Part 1 – General Mango Nutrition

(QDAF, 2015)

Tropical Horticultural Consulting
HAL Horticulture Australia
amia Australian Mango Industry Association Ltd
Australian Government
Northern Territory Government
Queensland Government

Acknowledgements

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Pinata Farms

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General Mango Nutrition

Main module components

- Mango phenological cycle
- Essential nutrients
- Role of nutrients in mango growth
- Soil pH
- Leaf and soil testing

The Big Picture

- Healthy non-stressed trees are essential for best results.
- Nutrition is only one part of mango management.
- All management practices must come together.
- Climate/environmental effects are another factor.

Mango Phenology

- Study of the growth events of mango trees
- Growth draws heavily on
  - carbohydrate reserves and/or
  - current photosynthesis
- Nutrition, paclobutrazol, water, pruning, pest and disease control all affect growth
- Use phenology to fine-tune management

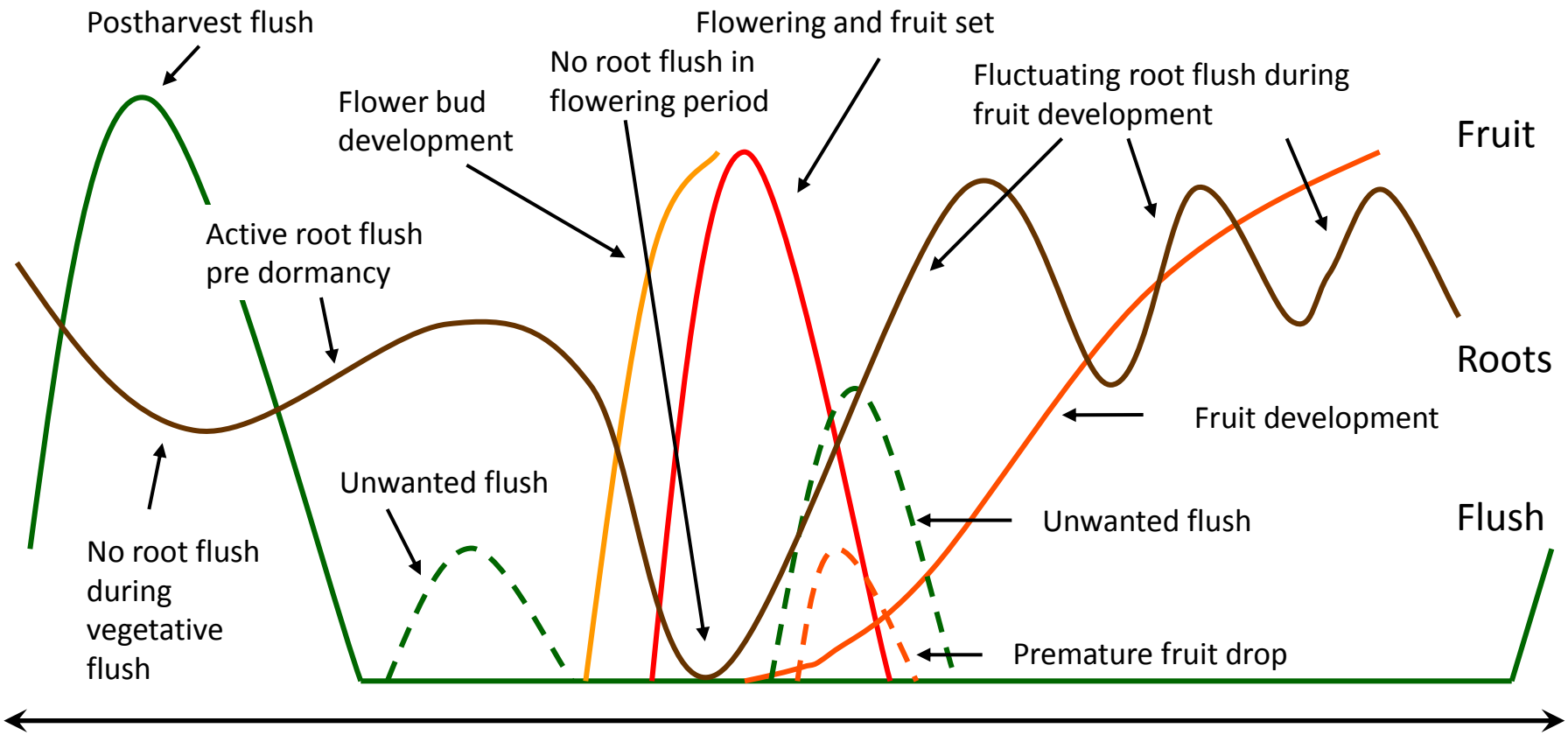
Annual phenological events

- Leaf and root flushes
- Dormancy
- Flowering and leaf flush
- Pollination
- Fruit set and development
- Fruit harvest






Mango phenology









Essential Elements

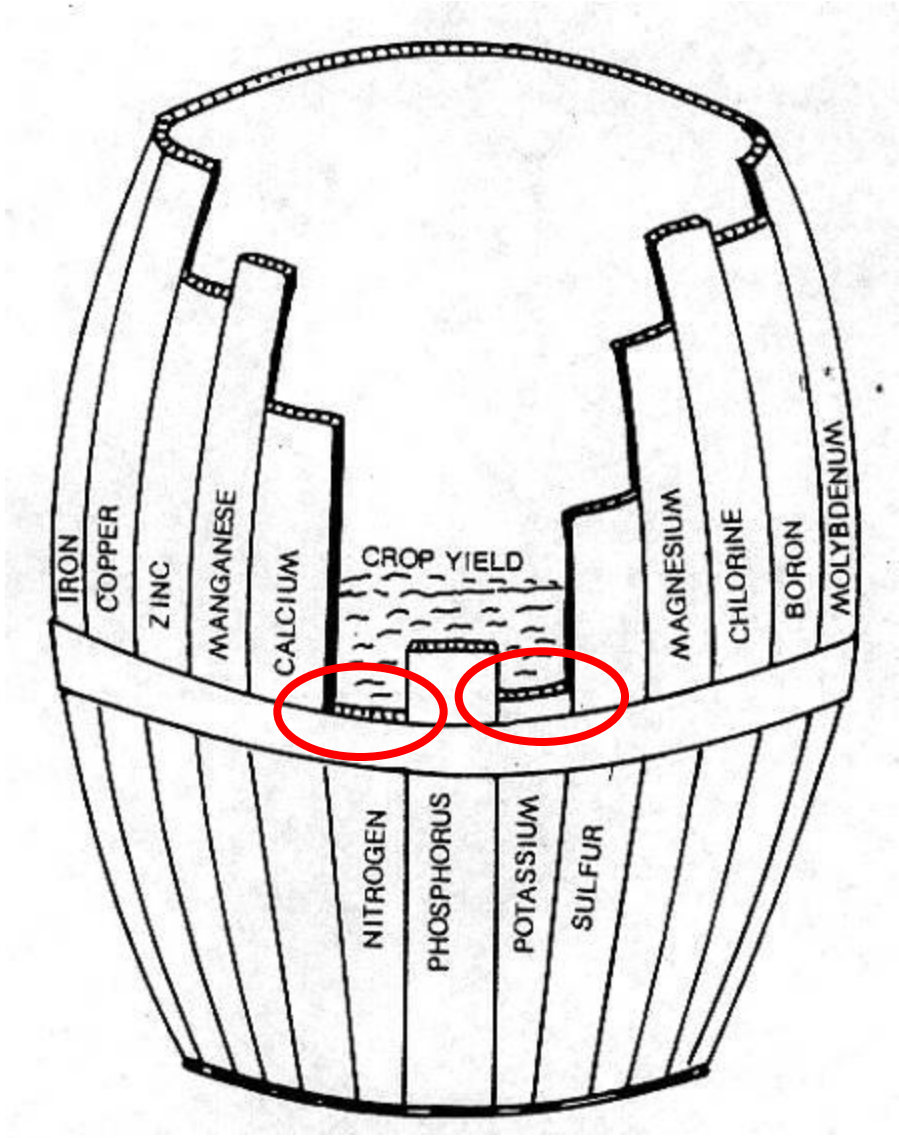
Macro elements

Nitrogen (N)
Phosphorus (P)
Potassium (K)
Calcium (Ca)
Magnesium (Mg)
Sulphur (S)

Trace elements

Boron (B)
Zinc (Zn)
Iron (Fe)
Copper (Cu)
Manganese (Mn)
Sodium (Na)
Chloride (Cl)
Molybdenum (Mo)

Nutrient balance



Law of Minimum Factor

- Level of water in barrel represents crop yield
- Restricted by most limiting nutrient i.e. nitrogen
- If nitrogen is added, the next most limiting nutrient is potassium

The Fantastic Four

All nutrients are important

The 4 most critical for mangoes are:

- Nitrogen
- Potassium
- Calcium
- Boron

Nitrogen

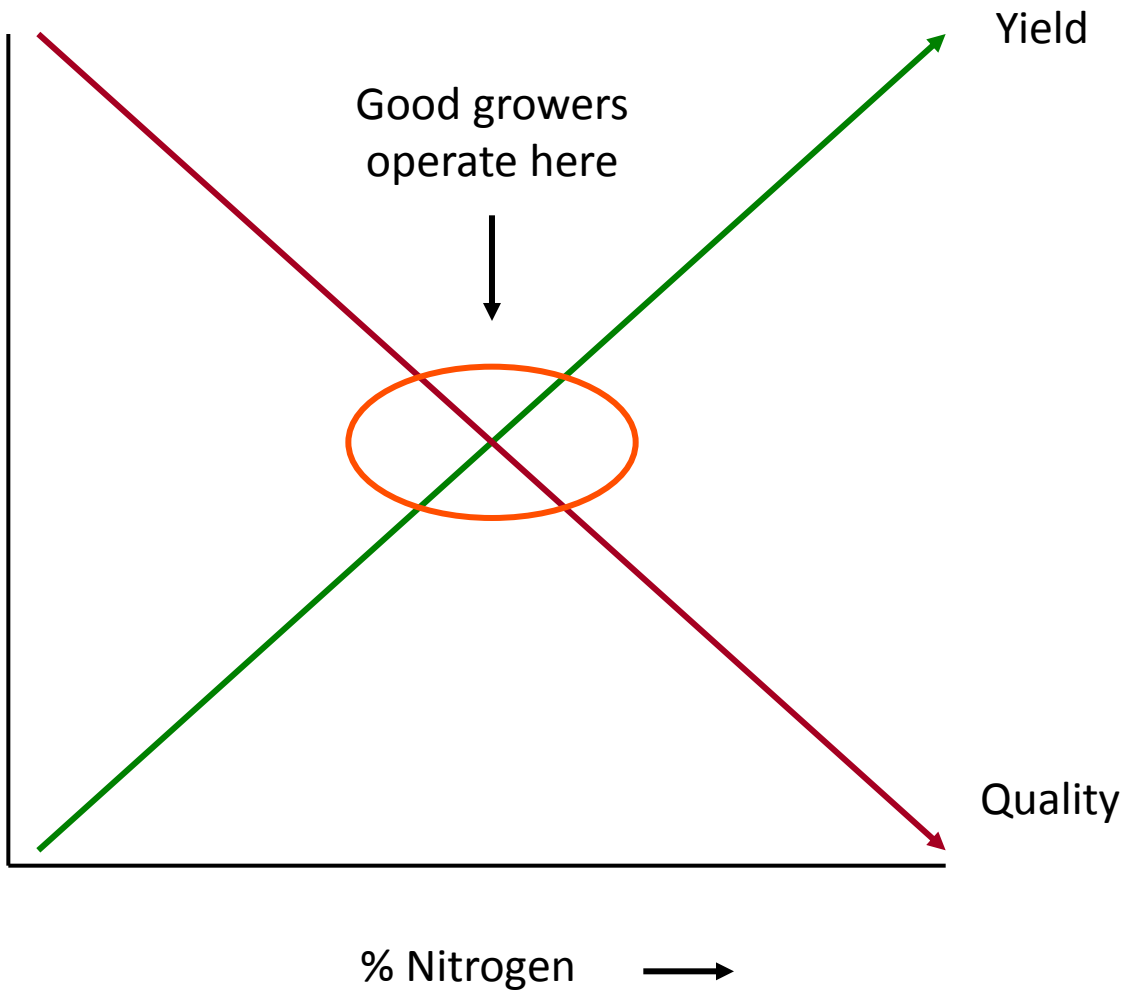
- Most important element for yield & quality
- Main nutrient affecting growth
  - flush, flowers, fruit & roots

- In mangoes, nitrogen
  - increases tree vigour
  - stimulates flowering in combination with K
  - improves fruit set, retention and yield
  - increases fruit size
  - increases brix

Nitrogen

- Readily translocated in soil & tree
- Trees readily respond to N
- Use, timing and rates vary across industry
- Application timed to growth events
- Influences levels of other nutrients
- Recommend sampling pre-flowering and post-harvest

The nitrogen relationship



Nitrogen (N)

- Approximately 78% of the earth's atmosphere is made up of Nitrogen Gas (N2)

In spite of this…

- The form of N required by plants is often limiting; plants can only take up N in the ammonium (NH4+) or nitrate (NO3-) form

Foliar leaf nutrition levels –

Applying N fertiliser increases uptake of other nutrients

Nutrient	Before N fertiliser	+ 12kg/Ha N only	Optimum level
N	0.7%	0.8% ↑	1.0 - 1.5%
K	0.36%	0.78% ↑	0.7 - 1.2%
Ca	1.17%	3.16% ↑	2.0 - 3.5%
B	43mg	60mg ↑	50 - 80 mg/kg

On Honey Gold in 2007- 08 pre-flowering

Foliar leaf nutrition levels –

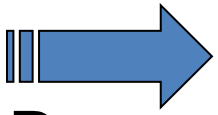
Applying N fertiliser increases uptake of other nutrients

Nutrient	Before N fertiliser	+ 12kg/Ha N only	Optimum level
Zn	21	56 ↑	20 - 150 mg/kg
Fe	20	30 ↑	70 - 200 mg/kg
Cu	39	39	10 - 20 mg/kg
Mn	55	410 ↑	60 - 500 mg/kg
B	43	60 ↑	50 - 80 mg/kg
Mo	<0.01	0.25 ↑	0.05 - 1.0 mg/kg

Nitrogen Deficiencies

- Poor vegetative and reproductive growth
- Decreased defense against disease

  - Reduction in fruit size
  - Poor yield
  - Increased fruit drop



Decreased $$$$

Excessive N or wrong timing - negative effects

- Early fruit set
  - direct Ca from fruit to leaves (leaves are bigger sink)
- Pre-harvest
  - excessive leaf growth
  - lowers K concentration
- Post-harvest
  - green, ripe fruit
  - less blush
  - softer fruit
  - increased postharvest rots
  - increased internal disorders (jelly seed, stem-end cavity, soft nose)

Which is more likely to support next year's crop?

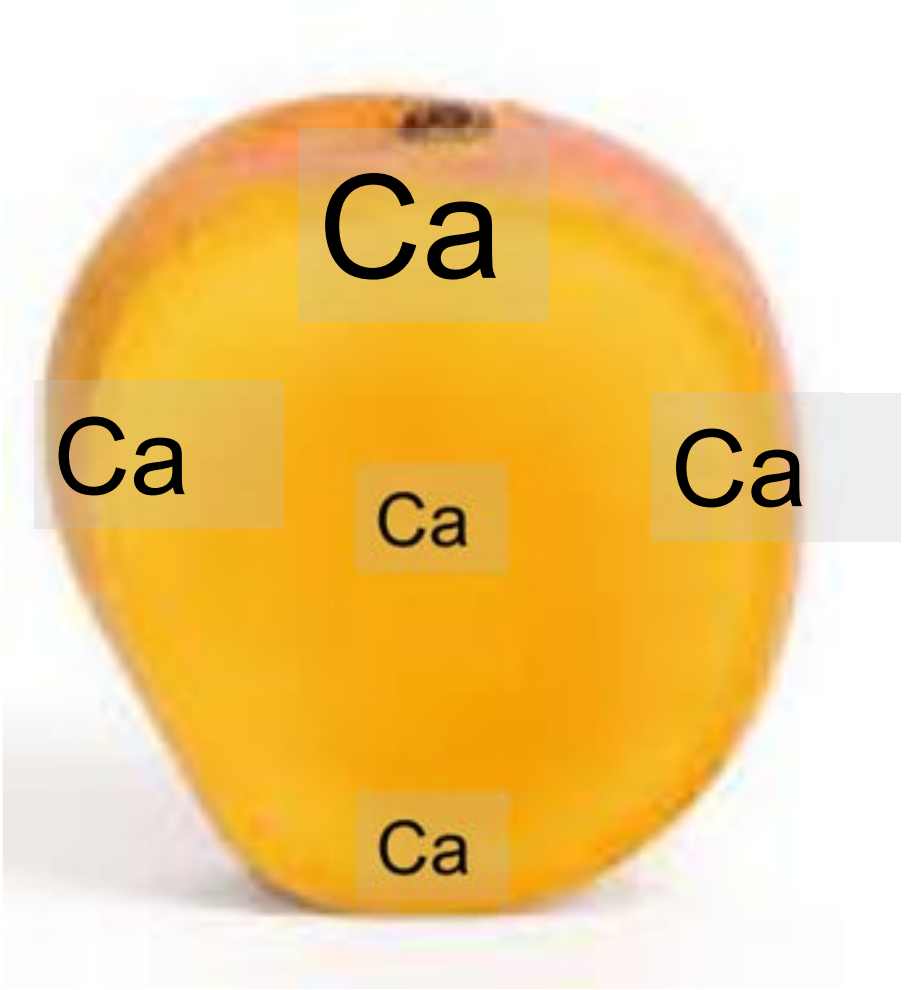
Calcium (Ca)

- Strengthens cell walls (structural component)
- Provides defense from pathogens
- Essential for root hair and leaf development
- Important during cell division
  - first 6-10 weeks of fruit development
- Important for fruit quality
  - firmness, shelf life & internal quality
- Needed all year round!

Calcium (Ca)

- Not easily translocated in the tree
- Uptake
  - passive, needs soil moisture
  - best by young roots
  - difficult to get in to fruit from soil or leaf
  - foliar applications of little use
- Uptake speed depends on particle size
- Easily outcompeted by other nutrients
- Plants use more Ca than any other added element

Calcium distribution in fruit

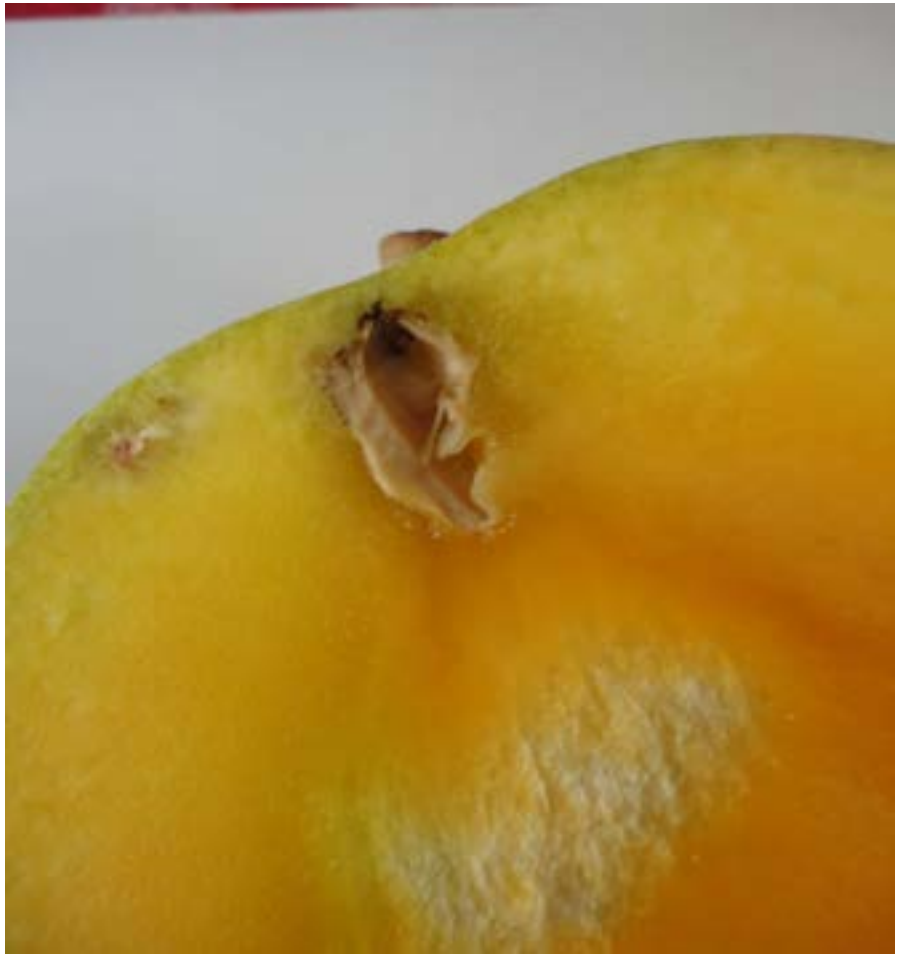


Calcium deficiency

Jelly seed

Calcium deficiency

Stem-end cavity



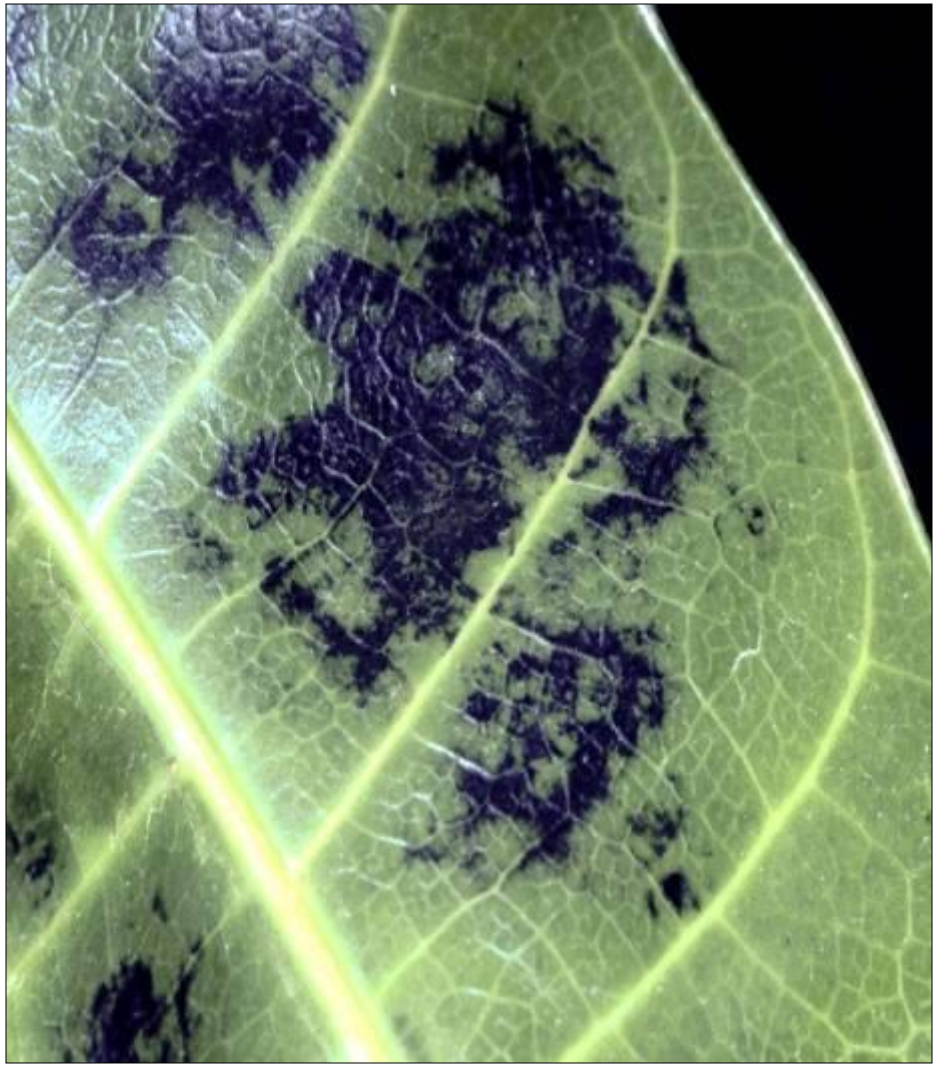
Calcium deficiency

Internal defects

Boron (B)

- Necessary for all new cell growth
  - flushing, flowering, pollination and fruit development
  - maximise B at flowering and fruit set
- Important in cell walls
- Helps Ca work and therefore fruit quality
- Can help with fruit set in cooler weather
- Affects hormone movement
- Mobile in the soil and but not in the plant
- Easy to go from deficiency to toxicity

Boron toxicity



Boron deficiency

Boron deficiency in fruit

Potassium (K)

- Role
  - Involved with water regulation, cell growth and expansion & movement of sugars
  - Activates enzymes in metabolic pathways
  - Thickens cell walls which increases resistance to pathogen and insect attack
  - Important for fruit quality - skin & flesh colour, flavour & fruit size
- Very mobile in the soil and the plant
- Greatest need is with fruit development

Potassium (K)

- K, Ca, Na, and Mg compete for uptake
- Deficiency reduces fruit size, yield and flavour
- Suppressive effect on powdery mildew (mono potassium phosphate)

Potassium deficiency

Photo: S. Srinivasan,
Tamil Nadu Agricultural University, India

Summary

- Nitrogen drives
- Calcium builds
- Boron activates
- Potassium sizes and sweetens

Other Important Nutrients

Phosphorus (P)

- Role
  - Important for cell division
  - Involved with the production and movement of energy within the plant
  - Important for seed (and therefore fruit) development
  - Initiates and develops root laterals
  - Necessary to get adequate uptake of other nutrients
- Very mobile in the plant but not in the soil
- Generally not limiting element in mangoes
- Soil pH affects uptake

Magnesium (Mg)

- Central molecule in chlorophyll
- Important for photosynthesis & aids phosphorus movement in the plant
- Very mobile in the plant and the soil
- Affects the uptake and availability of other cations (Ca and K)
- Timing need - during active vegetative growth phases
- Excessive Mg can green leaves and fruit

Mg deficiency

Sulfur (S)

- Constituent of plant proteins and photosynthesis
- Very mobile in the soil but not mobile in the plant
- Role in tree growth and fruit quality is not fully understood
- Low levels limit N uptake
- Timing - during all active growth phases
- Yellowing of all leaves could be sign of S deficiency

Zinc (Zn)

- Important for leaf expansion
- Involved with water regulation
- Essential for chlorophyll formation and hormone production
- Immobile in the plant – deficiency at growing points
- High P availability reduces Zn
- Deficiency causes stunted growth, yield decrease and fruitlet abscission
- Timing - during vegetative growth phases

Zn deficiency

Iron (Fe)

- Involved with water regulation in the plant and chlorophyll formation
- Immobile in the plant
- Timing - during vegetative growth phases
- Often low in many farms
- Higher levels in wet soil conditions

Fe deficiency

Manganese (Mn)

- Functions are similar to magnesium
- Helps chlorophyll formation
- Immobile in plant
- Often toxic in other crops, especially at low pH
- High Mn can restrict Ca movement to growing points

Mn toxicity

Photo (Mn toxicity on citrus)

Copper (Cu)

- Involved in photosynthesis, chlorophyll formation and fruit development
- High levels can lead to iron deficiency
- Timing - during vegetative growth phases
- Most trees get enough from foliar fungicidal sprays of copper.

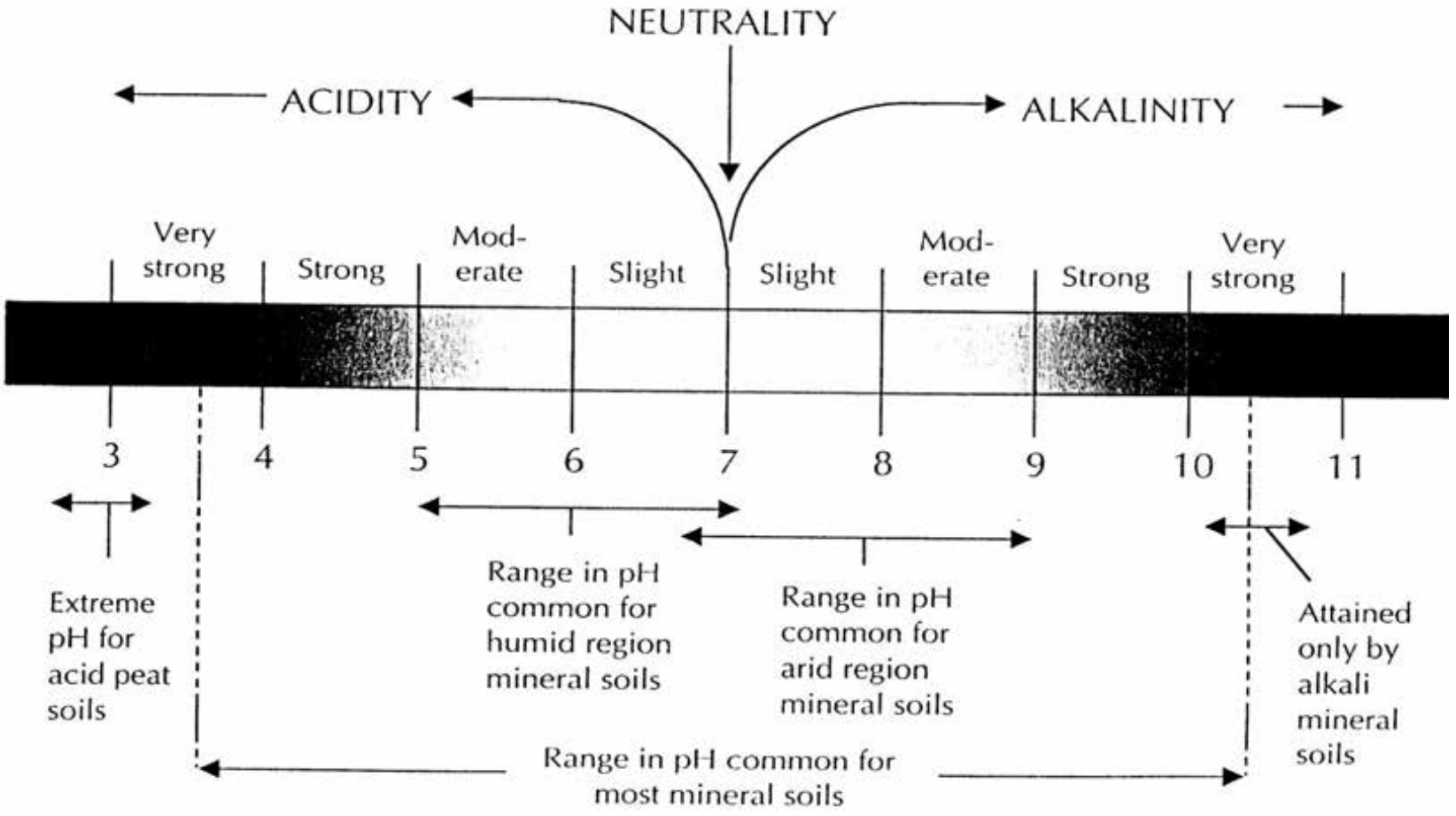
Molybdenum (Mo)

- Needed for N assimilation
- Enhance uptake of N, K and Ca
- Helps iron absorption, excess reduces iron availability
- Needed in extremely small amounts but deficiency affects growth and yield

Soil pH

- Measurement of soil acidity or alkalinity
- Soil pH (acidity or sweetness) affects nutrient solubility and plant availability.
- Need correct pH for mangoes to maximize nutrient availability

Soil pH Ranges



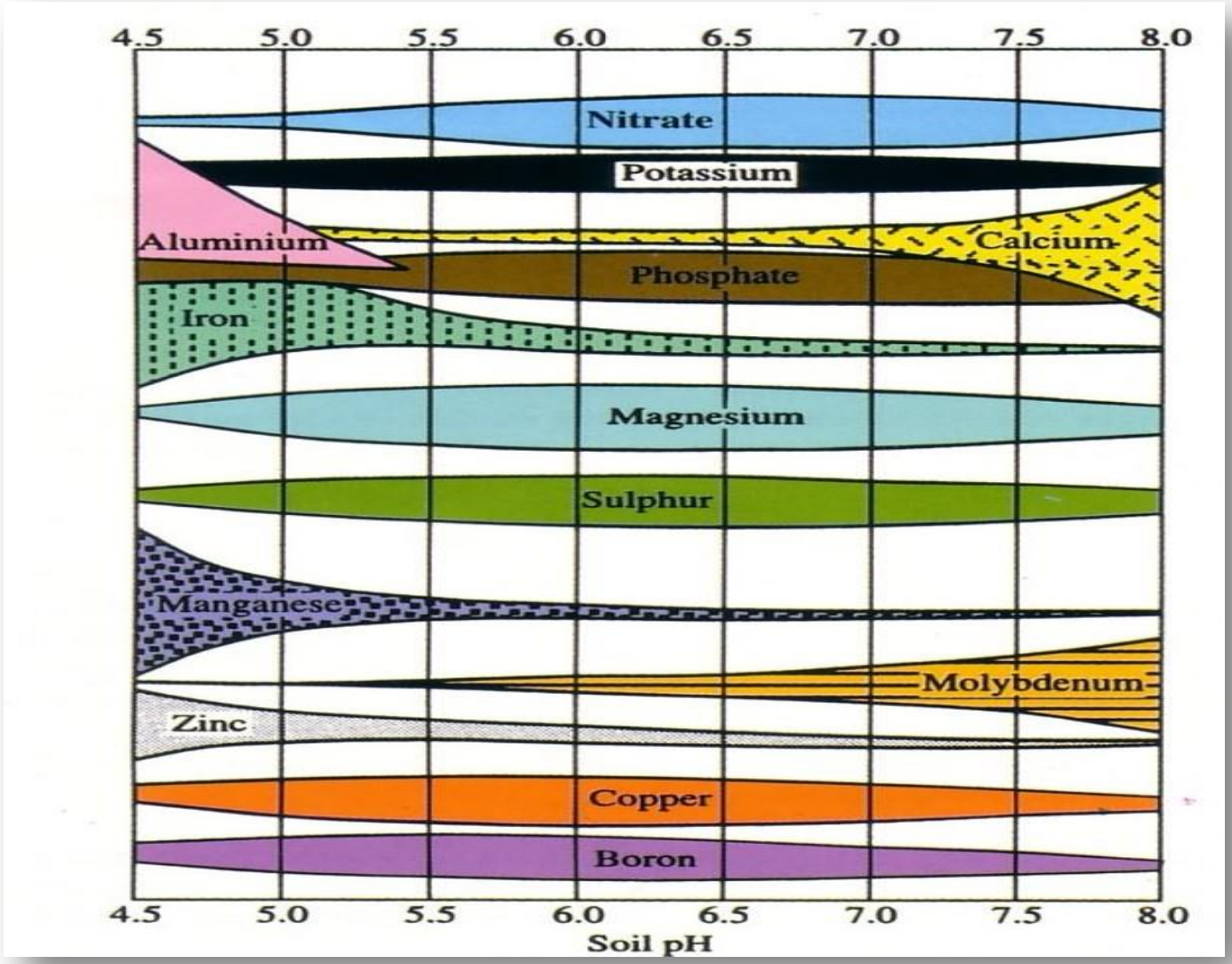
Factors decreasing soil pH

- Leaching losses of cations such as Ca and Mg
- Water saturated soil
- Erosion of alkaline surface soil
- Acid forming fertilisers such as DAP, SOA
- Addition of elemental S, aluminium sulphate or iron sulphate

Factors increasing soil pH

- Addition of lime/dolomite
- Irrigation water high in Na or Ca Carbonate or bicarbonate
- Erosion of acid or neutral top soil where pH increases with soil depth

Effect of pH on nutrient availability

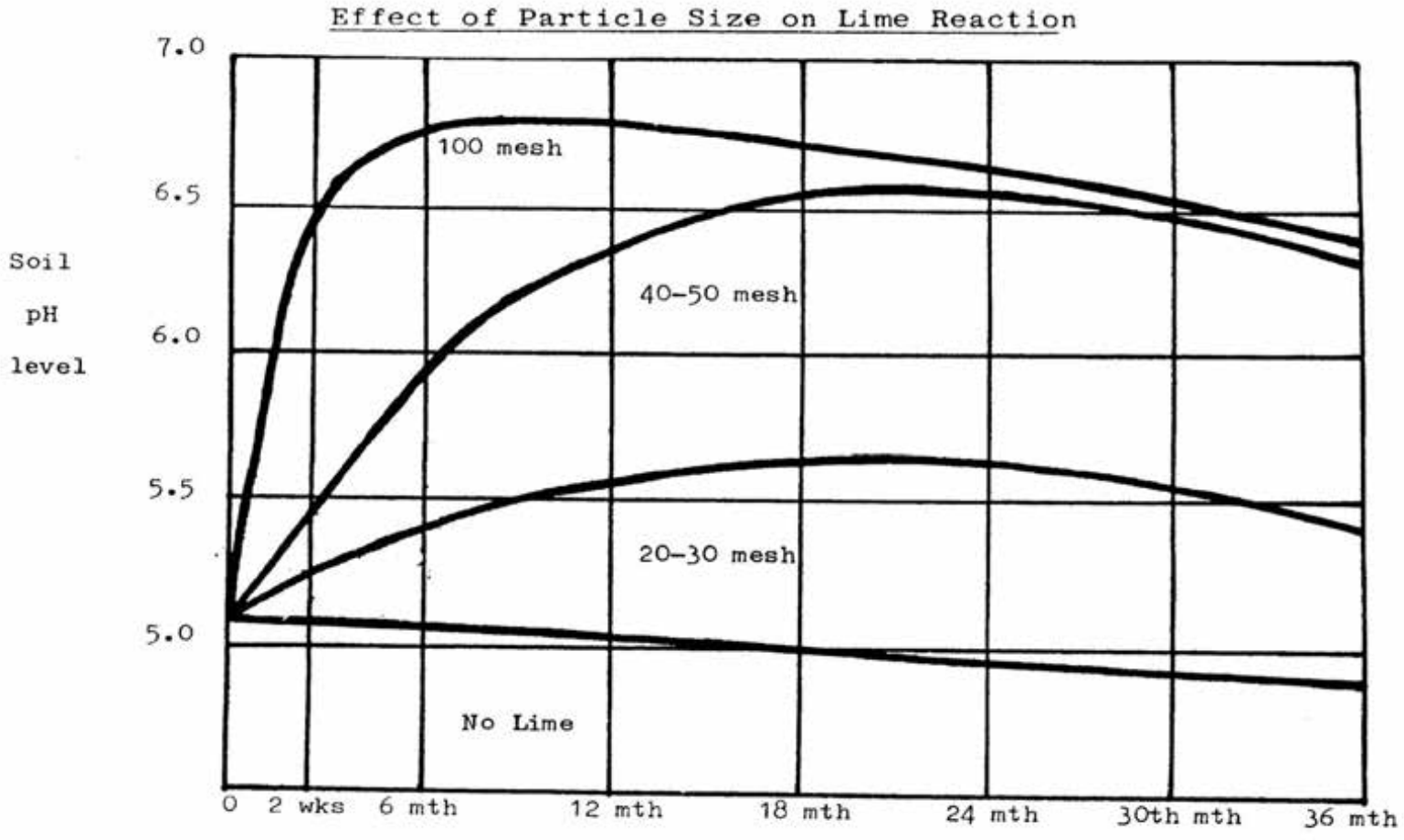


How to increase Soil pH

- 240 kg of lime/Ha will increase pH by 0.1
- 400 kg of dolomite/Ha will increase pH by 0.1
- Gypsum is neutral and will not affect pH

pH	Change	Lime	Dolomite
5.0	6.5	3.6 t/ha	6 t/ha
5.5	6.5	2.4 t/ha	4 t/ha
6.0	6.5	1.2 t/ha	2 t/ha

Effect of particle size on lime reaction



Lime worked into pasture soil.
NSW Irrigation R & E Committee Farmers Newsletter. June 1980. No 147. p 15

To lower soil pH (kg S/ha)

Soil pH	Sandy soils	Clay soils
7.5	440-660	880-1100
8.0	1100-1650	1650-2200
8.5	1650-2200	2200-3300
9.0	2200-3300	2300-3300
Western Fertilizer Handbook. Rates will vary depending on soil pH, texture, and buffering capacity		

Leaf and soil testing

Accuracy of results depends on:

- Good representative sample collection
- Choosing a good accredited laboratory
- Trained/proper interpretation of results

Leaf analysis

- Select average trees, not the best or worst.
- Sample twice annually (post harvest & pre-flowering)
- Procedure:
  - Sample mature leaves of the same age
  - DO NOT sample soft flush
  - Representative sample across block from average trees
  - 3rd or 4th leaf (last fully expanded leaf) from the growing tip
  - Take leaves from all 4 sides of the tree
  - Sample about 20 trees per block

Ideal sample leaves

Soil sampling

- Conducted annually after harvest
- Depth of 0-15 cm
- Inside drip-line of tree (or where watered)
- 2 samples/tree – one each side
- Sample about 20 trees/block
- Sample in conjunction with leaf samples.

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Part 2 – Designing a mango fertiliser program

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Nutrition management in mangoes
The 4 R's

The right nutrient choice

- a type needed by the tree

The right rate

- as the tree requires

The right time

- to match nutrient demand

The right place

- where the tree can access it

Relationships

- The 4 R's are interconnected and must be synchronized with plant, soil, climate, and management
- The 4 R's are essential to increase nutrient use efficiency and sustainability
- The 4 R's must be kept in balance

Keys to managing nutrition

- A regular nutrition pattern facilitates consistent yields across seasons.
- Removed nutrients need replacement
- Critical elements need to be supplied at the right growth stages
- Fertiliser application needs to be matched to phenological demands

Annual phenological events

- Fruit harvest
- Leaf and root flush
- Dormancy
- Flowering and leaf flush
- Fruit set and development
- Fruit harvest







Match application to demand

- Encourage strong post-harvest growth flush
  - protect and feed this flush, this is your next crop
- Ensure dormancy period
  - 2-3 month during autumn/winter
  - set up flushes for flowering
- Reduce stress during key times of flowering, fruit set and development (nutrition, irrigation, pest/disease).







Strong flush post-harvest

Determining the right nutrients & rates

- Understanding the stages of mango phenology
- Grower site knowledge and experience
- External advice (Advisors & Extension)
- Results of leaf and soil tests
- Calculation of nutrient removal & losses
  - Crop and vegetation removal
  - Leaching (N,K)
  - Volatilisation (N)
  - Soil loss/water runoff (Ca)

Optimum plant leaf levels for mango

Nutrient	Units	Desired range
Nitrogen	**(% N)**	**1 - 1.5**
Sulphur	(% S)	0.1 - 0.2
Phosphorus	(% P)	0.1-0.2
Potassium	**(% K)**	**0.75 - 1.2**
Calcium	**(% Ca)**	**2.0 - 3.5**
Magnesium	(% Mg)	0.15 - 0.4
Sodium	(% Na)	<0.20
Chloride	(% Cl)	<0.25
Boron	**(ppm B)**	**50 – 70**
Zinc	(ppm Zn)	20 - 100
Copper	(ppm Cu)	10 - 20
Iron	(ppm Fe)	30 – 120
Manganese	(ppm Mn)	60 – 500
Molybdenum	(ppm Mo	(0.05-1.0)

Optimum soil levels for mango

Element	Optimum Soil Level
pH	5.5 – 7.0
Organic Carbon	1-3 %
Conductivity	< 0.2 dmS
Nitrogen	<10
Phosphorus (Colwell)	60 - 80
Potassium	0.25 – 0.4 meg/100 g
Sulphur	> 12 mg/kg
Sodium	<1.0 meg/100 g
Chlorine	<250 mg/kg
Calcium	3 - 5 meg/100 g
Magnesium	0.75 – 1.25 meg/100 g
Copper	0.3 – 10 mg/kg
Zinc	2 – 15 mg/kg
Manganese	4 – 50 mg/kg
Iron	4 - 100 mg/kg
Boron	1 - 2 mg/kg
Cation Exchange	~5
% Sodium	< 1%
% Potassium	5 %
% Calcium	65 – 80%
% Magnesium	15 -20 %

Different soils = different management

- High CEC =

  High nutrient and water retention capacity

- Low CEC =

  Low water and nutrient retention capacity

Effect of soil type on CEC

Mango optimum CEC is > 5

- Sands 2-3
- Sandy Loams 2-12
- Loams 5-20
- Clay Loams 5-20
- Clays 10-80+

Nutrient removal & losses

Caused by:

- Crop and vegetation removal
- Leaching (N,K)
- Volatilisation (N)
- Soil loss/water runoff (Ca)

Nutrient removal by fruit (10t/Ha)

Nutrient	Amount removed	Estimated fertiliser efficiency	Replacement nutrient required
Nitrogen	8.5 kg	40%	21kg N
Potassium	12.9 kg	60%	22kg K
Calcium	11.5 kg	80%	14kg Ca
Boron	2.0	40%	5kg B

Leaf N% can drop from 1.0% to 0.7% with good flowering

Common nutrient loss estimates

N	30 to 50% by leaching, volatilisation
P	50 to 100% by fixation
K & Mg	20 to 30% by leaching
Ca & S	5 to 20% by soil erosion or run off
B	Up to 60% by leaching

Nitrogen fertilisation

- Rate based on leaf test results
- Greatest demand during growth
  - post harvest and flowering
- N increases fruit size and number
- Apply frequently on lighter soils
- Adjust rate with crop load
  - More on heavier crops
- Green trees are not always due to high N
  - High Mn, Zn, Mg, and Paclobutrozol can also green trees

Suggested pre-flower leaf N levels

Cultivar	Optimum % Leaf N
KP	1.1 – 1.3
R2E2	1.3 – 1.4
Honey Gold	1.3 – 1.4
Calypso	1.0 – 1.5
Keitt	1.0 – 1.2
Other – Asian cultivars	1.2 – 1.4

N fertiliser needs based on pre-flower leaf levels

Leaf N (%)	N by canopy m^2	Urea by canopy m^2	Urea by $10m^2$
<1.0%	8g	17g	170g
1 – 1.3%	4g	9g	90g
1.3 – 1.5%	0g	0g	0g
>1.5%	Excessive level, Avoid N fertiliser		

Based on Honey Gold trials 2007-10, does not apply to Keitt

Use about 2/3^{rds} on KP

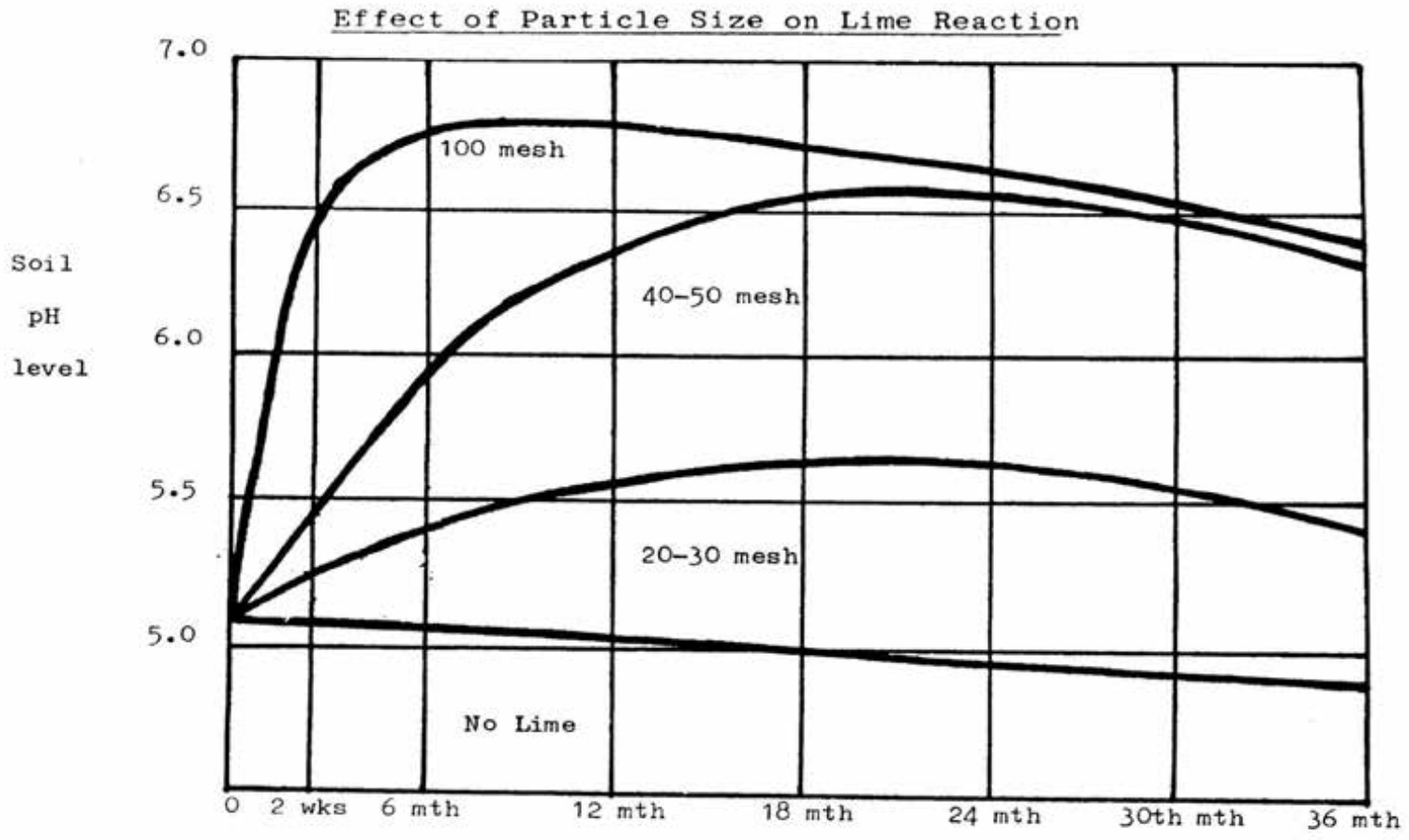
Organic nitrogen sources

- Hay mulch and inter-row slashings
- Plant extracts
- Animal manures

Calcium fertilisation

- Leaf 2 – 3.5 % & Soil of 3-5 meq/100 g
- Rate based on leaf and soil tests
- Form depends on soil pH
- Moisture needed for uptake
  - spread near end of wet
- Finer particles absorbed quicker
- Use liquid form during flowering and early fruit development
- Apply to suit root flush timing

Effect of particle size on lime reaction



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Boron fertilisation

- Leaf 50-70 mg/kg or ppm
- Soil level depends on soil type
  - lower amount on lighter soil types
  - apply more frequently on lighter soils
- Rate based on soil and leaf test results
- Needed each time there is new growth
- Foliar applications to soft tissue only
  - during flowering
  - poor uptake on old leaves

Potassium fertilisation

- Leaf 0.75- 1.2% & soil 0.25 – 0.40 meq
- Rate based on soil and leaf test results
- Need K post harvest and flowering
- >60% over fruit filling period
- Easily leached - apply frequently in lighter soils
- Adjust rate with crop load – more on heavier crops

Considerations for applying fertiliser

Fertilizer by the handful !

Fertilizer	Average grams/handful for 6 people	Range measured
Urea	16.6 g	11.1 - 22.2 g
15-15-15	34.1 g	20.8 - 53.3 g
Conclusion: Use of term handful for describing rates can be very inaccurate!!!		

Right fertiliser placement

- Nutrients are taken up by fine small roots/root hairs.
- Where are most tree fine roots?
- Not next to tree trunk!!
- Where is irrigation zone?
- Spread evenly
- Some fertiliser best incorporated or some best banded

Where are mango feeder roots??

Fertiliser value

Cost per unit of nutrient

- Fertilizer costs are high and often money can be saved.
- In comparing the costs of one fertiliser with another, the price per tonne does not mean much. The cost per unit of nutrient is what is important.
- If for example you need N and you can buy it as either urea or sulphate of ammonia, you need to see which is cheaper.

To calculate unit cost of per kg of nutrient

$$\frac{\text{Price per tonne}}{\text{elemental \% x 10}} = \text{cost per kg of nutrient}$$

Urea is 46% N and Sulphate of Ammonia is 21% N

If Urea costs $960/tonne and S of A $640/tonne

Urea: $960/46*10 = $2.08 per unit N

S of A: $640/21*10 = $3.04 per unit N

Fertilizer Analysis

- NPK
- In some imported fertilisers, analysis is given as N-P_2O_5-K_2O rather than NPK. Therefore it is essential that labels of imported fertilisers be checked before use.
- To convert P_2O_5 to P, multiply by 0.44 and K_2O to K multiply by 0.83.
- Australia 15-15-15 is 15% N; 15% P; 15% K
- Asia 15-15-15 is 15% N; 6.6% P; 12.4 % K

Unit comparison

< Less than
> Greater than

1% = 10,000 ppm or 10 g/L

1 ppm = 1 mg/kg =1 mg/L

To convert meq/100 g to ppm or mg/kg
(meq/100 g x equivalent wt. x 10 = ppm)

To convert mg/kg to meq/100
(mg/kg / equivalent wt x 10 = meq/100 g)

Equivalent wt. Ca = 20 Mg = 12 K = 39 Na = 23

Speed of nutrient uptake from soil

Fast	Slow
Nitrates	Calcium
Potassium	Phosphorus
Sulphates	Iron
Magnesium	Copper
Zinc	Molybdenum???
Boron	
Manganese	
Sodium	
Chloride	

Mobility of nutrients in the plant

Mobile	Variably mobile	Immobile/Limited
Nitrates	Sulphur	Calcium
Phosphates	Copper	Manganese
Potassium	Zinc	Iron
Magnesium	Molybdenum	Boron
Sodium		
Chloride		

Incompatible Fertilisers

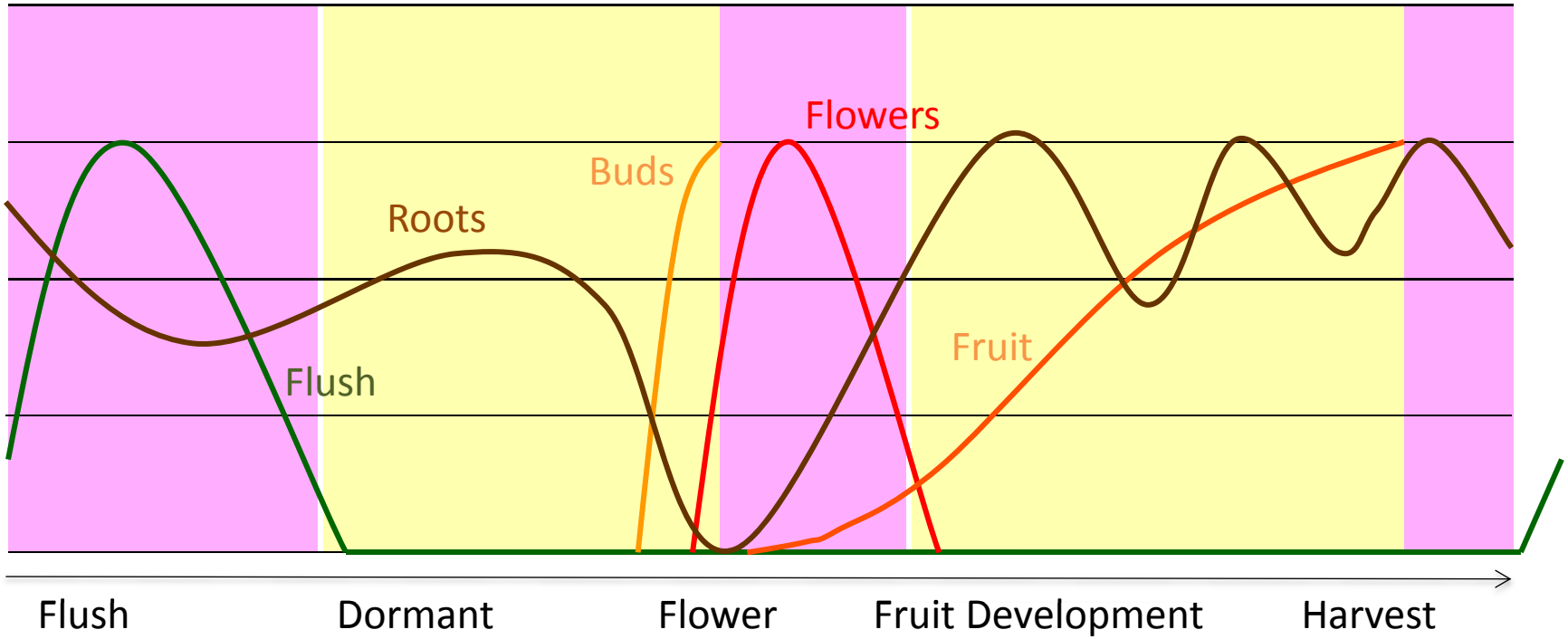
- Lime and superphosphate
- Dolomite and superphosphate
- Zinc and superphosphate
- Ammonium sulfate and lime
- Solubor and any sulphate
- Calcium Nitrate and any sulphate
- Monopotassium phosphate and magnesium sulphate

TAKE HOME MESSAGES

- Maintain healthy, non-stressed trees
- All management practices work together
- Nitrogen, Calcium, Potassium and Boron are the most important elements for mangoes
- Match nutrient application to tree demands.
- If you are not monitoring you are guessing!

Suggested key times for phonologically based fertiliser application to mangoes.

Phenology based nutrition

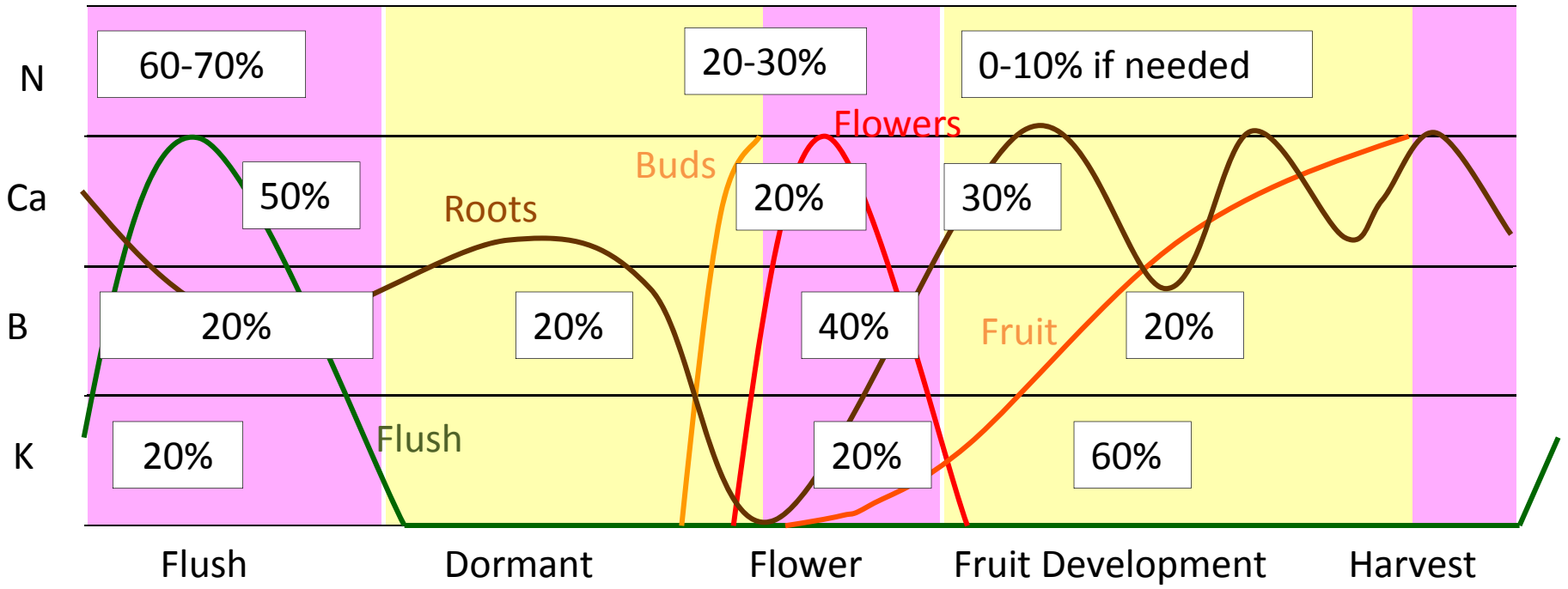







Critical Windows for Application

(eg 50kgN/year. Apply 60-70% at flush, 20-30% at budding/early flowering and 0-10% during fruit development)



Thank You