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RAMBUTAN NUTRIENT REQUIREMENT AND MANAGEMENT

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Rambutan Nutrient Requirement and Management

TK Lim, L. Luders, Y. Diczbalis and M. Poffley

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SUSTAINABLE AGRICULTURE

THE DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES IS COMMITTED TO THE PRINCIPLES AND PRACTICES OF SUSTAINABLE AGRICULTURE

Definition:

Sustainable agriculture is the use of practices and systems which maintain or enhance:

- the economic viability of agricultural production:
- the natural resource base: and
- other ecosystems which are influenced by agricultural activities.

Principles:

1. Agricultural productivity is sustained or enhanced over the long term.
2. Adverse impacts on the natural resource base of agricultural and associated ecosystems are ameliorated, minimised or avoided.
3. Harmful residues resulting from the use of chemicals for agriculture are minimised.
4. The nett social benefit (in both dollar and non-dollar terms) derived from agriculture is maximised.
5. Agricultural systems are sufficiently flexible to manage risks associated with the vagaries of climate and markets.

SUSTAINABLE AGRICULTURE IN THE NORTHERN TERRITORY

Introduction

The establishment of fertiliser recommendations for fruit trees must be based on rational interpretation of sound plant and soil analyses taking into account the crop phenology, crop nutrient removal, leaf nutrient status, crop yield, nutrient recycling, soil type and characteristics, meteorological conditions and sources of fertilisers used. For perennial fruit trees soil analyses alone are not as useful as plant analysis in rationalising the fruit nutrient requirement, thus both are required. Beside fertiliser recommendation, plant analysis is an indispensable tool for a) the diagnosis and treatment of plant nutrient deficiencies, imbalances and toxicities; b) monitoring the efficacy of current fertiliser practices; c) establishing optimum levels of nutrient in plants; d) assessing the removal of key elements by the crop; and e) predicting and allowing for manipulation of crop yield and quality to a certain extent.

Interpretation of plant analysis

Various approaches have been used in the interpretation of plant analysis. The traditional method of leaf nutrient interpretations using critical nutrient concentrations (critical values) or sufficiency range do not account for the dynamic nature of foliar nutrient composition influenced by the physiological stage of crop growth, nutrient interactions and interactions between nutrients, dry matter accumulation and metabolic activities. A critical value is the concentration of nutrient in a particular plant part sampled at a particular growth stage at which a 5-10% reduction in yield is observed. Meeting the requirement that plant tissues be sampled at a particular stage is not always convenient. Sufficiency ranges have been proposed such that the lower limit represents roughly the critical level and the upper limit is set at a value corresponding to unusually high concentration. Contrary to giving flexibility to diagnoses they lead to decrease in diagnostic precision because the limits are far too wide. To overcome such limitations the Diagnosis and Recommendation Integrated System (m-DRIS) method was evolved by Beaufils in 1973 and has since undergone considerable modifications. The m-DRIS method in its various modified versions has been successfully developed as a reliable diagnostic tool and applied to many annuals and perennial crops including fruit trees. The m-DRIS approach minimises the effect of physiological age of tissue enabling sampling of wider tissue age than is permissible under the critical value method. It considers nutrient interactions and other factors and computes nutrient balance indices in order of limitations as being negative (deficient), positive as excess and zero as balance using nutrient ratios.

Leaf and soil sampling

A sound leaf analysis interpretation is dependent on a good uniform plant sampling procedure. Young immature leaf tissues are generally the most sensitive for immobile elements like Ca and B while older leaf tissues more sensitive for the phloem-mobile elements like N, P, K, Mg and the other micro-nutrients. We standardised the method as follows: taking the middle leaflet pair of the latest mature green (RHS green group 140 C,) vegetative flush ie. the third and fourth leaves from the shoot terminal (Table 1). This is the best leaf age to sample as most leaf nutrients levels except for calcium and boron are comparatively the least variable with the lowest coefficients of variability *circa* 20%. Ten to 20 random leaflet sub-samples from 4 quadrats of the tree are then bulked. However, for diagnosis of Ca or B deficiency the immature light green (RHS green group 140A) should be taken. At the same time, 4 soil cores 15-20 cm deep, should be taken from each tree and bulked for soil analysis. The number of samples to take depends on the size of the block eg. 4 final leaf samples and soil samples for an average 20 ha block. The best sampling time for leaf analysis is when most leaf nutrients levels are comparatively the most stable and with the lowest coefficients of variability *circa* 20%. For rambutan in the Darwin region our studies indicate that this occurs in May/June, ie. just before flowering (Table 2).

Rambutan leaf nutrient norms - sufficiency range and m-DRIS norms and ratios

The mean nutrient levels in rambutan leaves, the sufficiency range for the nutrients and the m-DRIS norms for the individual elements and ratios are shown in Table 3. These have been computed from 4 years of nutrient logging at bimonthly intervals of 7 rambutan orchards involving more than 500 samples. The sufficiency range standards are established by taking the 95% confidence interval about the mean percent concentration of nutrients at May/June sampling period.

Rambutan soil nutrient status

Rambutan is grown mainly on the red and yellow brown earths or kandosols in the NT. The mean soil properties of the rambutan orchard in the NT computed from more than 500 samples taken over 4 years from 7 rambutan orchards are shown in Table 4. The mean pH level of 6.27 is within the optimum range of pH 5.5-6.5. The orchards around Darwin tend to have a low

Table 1. Variability in rambutan leaf nutrient status at different physiological stages (recommended stage shown in bold).

Leaf stage		N	P	K	Ca	Mg	S	Cl	Cu	Zn	Mn	Fe	B	Na
Light green (Green group 140A)	Mean	1.668	0.342	1.218	0.187	0.132	0.133	0.028	9.333	25.500	103.333	46.167	20.333	0.004
	SD	0.540	0.059	0.144	0.034	0.026	0.027	0.017	2.160	3.937	27.245	10.998	1.751	0.001
	CV	32.369	17.307	11.831	18.454	20.046	19.937	60.791	23.146	15.439	26.366	23.823	8.612	14.084
Green (Green group 140B)	Mean	1.860	0.320	1.000	0.593	0.272	0.200	0.043	8.500	94.667	448.000	222.167	56.000	0.010
	SD	0.225	0.080	0.154	0.397	0.123	0.023	0.010	1.378	40.053	216.891	76.690	15.672	0.005
	CV	12.089	24.922	15.375	66.982	45.108	11.402	23.834	16.217	42.310	48.413	34.519	27.985	52.416
Mature green (Green group 140C)	**Mean**	**1.618**	**0.328**	**0.767**	**0.828**	**0.322**	**0.240**	**0.053**	**5.833**	**119.833**	**618.000**	**281.333**	**80.333**	**0.012**
	SD	**0.208**	**0.064**	**0.104**	**0.385**	**0.074**	**0.042**	**0.019**	**0.983**	**20.808**	**253.077**	**52.481**	**8.937**	**0.004**
	CV	**12.828**	**19.589**	**13.572**	**46.528**	**23.132**	**17.678**	**34.911**	**16.855**	**17.364**	**40.951**	**18.654**	**11.125**	**34.993**

Table 2. Variability in rambutan leaf nutrient levels at different sampling times (recommended sampling time shown in bold).

		N	P	K	Ca	Mg	Na	Cl	S	Cu	Zn	Mn	Fe	B
Jan	Mean	1.54	0.20	0.62	0.70	0.42	0.038	0.06	0.15	8.58	27.14	124.60	50.93	49.25
	SD	0.30	0.04	0.19	0.27	0.17	0.054	0.04	0.02	5.84	23.08	123.02	37.98	20.61
	CV	19.29	22.32	31.10	38.96	41.52	142.144	67.95	13.48	68.08	85.07	98.72	74.58	41.86
Mar	Mean	1.77	0.23	0.83	0.68	0.43	0.011	0.05	0.16	11.69	25.59	121.61	49.79	38.09
	SD	0.32	0.05	0.27	0.22	0.18	0.010	0.03	0.02	13.09	19.86	103.38	40.58	23.16
	CV	18.05	21.13	32.13	32.11	41.62	98.413	60.17	14.04	111.96	77.63	85.01	81.50	60.79
May	**Mean**	**1.69**	**0.23**	**0.76**	**0.68**	**0.43**	**0.01**	**0.06**	**0.17**	**14.94**	**42.25**	**125.67**	**82.74**	**55.94**
	SD	**0.31**	**0.05**	**0.18**	**0.21**	**0.17**	**0.01**	**0.05**	**0.02**	**20.82**	**25.25**	**105.40**	**46.71**	**24.70**
	CV	**18.41**	**21.46**	**23.96**	**30.80**	**38.93**	**52.65**	**89.37**	**13.21**	**139.35**	**59.76**	**83.87**	**56.45**	**44.16**
Jul	Mean	1.83	0.21	0.86	0.67	0.42	0.02	0.10	0.16	27.44	48.46	163.09	95.81	53.04
	SD	0.31	0.05	0.21	0.22	0.17	0.02	0.08	0.03	33.43	28.76	142.13	57.07	23.17
	CV	16.80	23.52	24.09	32.11	40.17	132.40	79.28	19.48	121.85	59.35	87.15	59.57	43.68
Sep	Mean	1.58	0.21	0.73	0.72	0.43	0.02	0.13	0.16	22.39	48.12	130.62	92.20	49.27
	SD	0.31	0.05	0.19	0.22	0.16	0.01	0.11	0.02	26.85	31.25	108.55	54.90	16.77
	CV	19.75	23.46	25.52	30.09	36.39	51.04	81.36	13.96	119.94	64.94	83.10	59.54	34.03
Nov	Mean	1.64	0.22	0.70	0.67	0.42	0.02	0.08	0.16	12.77	31.06	103.91	54.48	41.11
	SD	0.27	0.05	0.20	0.24	0.17	0.02	0.07	0.02	15.98	26.90	99.85	43.82	10.98
	CV	16.59	22.30	28.77	36.11	39.95	105.35	85.34	15.35	125.16	86.62	96.09	80.44	26.71

Ca:Mg ratio (~ 2) which ideally should be around 6. This means that more calcium is needed in most orchards. The K:Mg ratio and the C:N ratio is close to the optimum 0.5. and 20:1 respectively for these soils. However, the high standard deviation of the K:Mg ratio indicates wide variability of these elements among the orchard soils. The C:S ratio is way above 400:1 indicating that sulphur is being immobilised and has to be replenished by using sulphur fertilisers. One suggestion is to use calcium sulphate to rectify both calcium and sulphur levels. Also soils low in sulphate tend to increase uptake of chlorine when it is available and rambutan is sensitive to high chlorine levels.

Fertiliser grade, ratio and formulation

Fertilisers are usually expressed in terms of mineral nutrient grades of 3-4 of the significant macro-elements. Fertiliser grade is the minimum guaranteed percentage of plant nutrients in a fertiliser. Two general ways are used to express these grades:

i) an oxide basis eg. N: P_2O_5: K_2O or N: P_2O_5: K_2O

ii) an elemental basis eg. N:P:K or N:P:K:Mg.

The latter is more universally used and is most widely accepted. To convert the oxide to the elemental basis and vice-versa the following equations can be used:

$$P_2O_5 \times 0.44 = P, \qquad K_2O \times 0.83 = K \qquad MgO \times 0.6 = Mg$$

$$P \times 2.29 = P_2O_5 \qquad K \times 1.20 = K_2O \qquad Mg \times 1.667 = MgO$$

For example the common NPKMg fertiliser for fruiting trees expressed as 12:12:17:2 on an oxide basis is 12:5:14:1.2 on an elemental basis and means that the fertiliser contains 12% total N, 5% available P, 14% K and 1.2% Mg.

The ratio of a fertiliser refers to the proportion of one plant nutrient percentage to another. for example a 10:10:10 NPK fertiliser has equal percentages of N, P, and K and has a ratio of 1:1:1. Formulation refers to the amounts of the various sources of plant nutrient materials used in the fertiliser.

Rambutan nutrient removal

Studies here and elsewhere have shown that rambutan removes a lot of N and K from fruits and harvested twigs. In rambutan fruit the sequence of nutrient removal is as follows: N>K>Ca>Mg>P. Our crop nutrient monitoring studies show that rambutan requires more N

Table 3. Sufficiency range and m-DRIS norms of rambutan leaf nutrient levels for the NT.

Element/ ratio	Sufficiency range	m-DRIS norms
N %	1.54-1.68	1.67
P %	0.21-0.23	0.22
K %	0.69-0.77	0.75
Ca %	0.68-0.77	0.69
Mg %	0.41-0.48	0.42
Na %	0.01-0.02	0.02
Cl %	0.11-0.13	0.1
S %	0.16-0.17	0.16
Cu mg/kg	16-25	16.34
Zn mg/kg	43-54	37.20
Mn mg/kg	104-150	128.30
Fe mg/kg	77-98	71.17
B mg/kg	43-55	47.86
n/p		8.09
n/k		2.40
n/ca		2.77
n/mg		4.68
p/k		0.31
p/ca		0.35
p/mg		0.58
k/ca		1.28
k/mg		2.17
ca/mg		1.81

Table 4. Mean soil properties of rambutan orchard soils in the NT.

Soil property	Mean value	SD
Electrical conductivity mS/cm	0.05	0.04
pH	6.27	0.67
Total nitrogen %	0.1	0.04
Organic carbon %	2.08	4.49
C:N	23:1	75.65
HCO_3 mg/kg	155.07	112.92
Cl mg/kg	8.54	10.33
P mg/kg	63.3	61.17
S mg/kg	15.09	17.23
Zn mg/kg	2.84	2.61
Fe mg/kg	56.05	61.58
K cmol (+)/kg	0.97	0.5
Ca cmol(+)/kg	4.43	2.38
Mg cmol(+)/kg	3.32	2.31
CEC cmol(+)/kg	8.72	4.11
Ca:Mg	1.95:1	1.43
K:Mg	0.55:1	0.69

and K than P especially during fruit development (Fig. 1 & 2). For every 100 kg of fruit and 100 kg of twigs removed per hectare, the following amounts of macro-elements are removed:

Fruits = N - 199 g, P - 26.8 g, K - 152 g, Ca - 72 g, Mg - 36.78 g

Twigs = N - 256 g, P - 390 g, K - 240 g, Ca - 171 g, Mg - 32 g.

During harvest the weight of twigs harvested with the fruits is around 10% of the fruit weight harvested.

Table 5. Macro-nutrients removed by harvested rambutan fruit.

Tree age	Fruit Yield	Twigs harvested	Nutrients removed in g during fruit harvest				
year	kg/tree/year	kg	N	P	K	Ca	Mg
3	10	1	22.46	6.6	17.6	8.91	4.00
4	15	1.5	33.69	9.9	26.4	13.365	5.99
5	20	2	44.92	13.2	35.2	17.82	7.99
6	30	3	67.38	19.8	52.8	26.73	11.99
7	40	4	89.84	26.4	70.4	35.64	15.98
8	50	5	112.3	33	88	44.55	19.98
9	60	6	134.8	39.6	105.6	53.46	23.98
10	75	7.5	168.5	49.5	132	66.825	29.97

Fertiliser application rates

We have to replenish the amounts shown above as well as the amount of nutrients consumed for flower, fruit, root, leaf and twig/branch growth; nutrients removed by pruning branches: nutrients lost from leaching, run-off, volatilisation and immobilisation in the soil. Also, in general fertiliser usage, we have to account for the expected efficiencies which are approximately 30-70% of added N, 5-30% of added P, 50-80% for added K. Leaves do replenish some nutrients from recycling but the amount is not known for rambutan. A suggested schedule for rambutan is:

Planting hole

During planting, 200g superphosphate, 100 g dolomite and 1 kg well decomposed organic manure are thoroughly mixed with top soil in the planting hole.

Non-bearing tree

For a non-bearing tree, an NPK = 10:4:8 grade fertiliser applied 5-6 times for year 1 and 2 commencing 3 months after planting is recommended. The rates are:

year 1 0.5 kg/tree/year,

year 2 1 kg/tree/year.

Bearing trees

Using the current NPK fertiliser 11:8:12 grade for fruiting trees, comparatively much P is wasted. In fact the composition of all three elements can be reduced. The NPK granular fertiliser should be chloride free as rambutan is extremely sensitive to chloride levels higher than 0.018%. Chloride toxicity is usually characterised by chlorosis and necrosis near the leaf margin, tips and often accompanied by defoliation of young leaves. Adequate amount of chloride is provided by irrigation water and by chloride impurities in fertiliser mixtures.

One guideline is to use a N:P:K = 10:5:9 (chloride free) fertiliser for fruiting trees as follows:

Table 6. Fertiliser schedule for fruiting rambutan trees.

Tree age year	Yield kg/tree/year	Fertiliser kg/tree/year	Nutrients in g /tree/year N	P	K
3	10	2.0	200	100	180
4	15	2.5	250	125	225
5	20	3.0	300	150	270
6	30	3.5	350	175	315
7	40	4.0	400	200	360
8	50	4.5	450	225	405
9	60	5.0	500	250	450
10	75	5.5	550	275	495

The above quantities should be increased with increasing yield and age of trees. Also the quantities have to be adjusted according to leaf nutrient levels revealed by regular leaf and soil nutrient analyses and, if rambutan trees are heavily pruned for that year, more nutrients should be applied.

Timing and frequency of granular fertiliser application

Based on our crop phenological studies and analysis of the crop nutrient requirement using a modified DRIS technique, rambutan consumed more nitrogen and potassium than phosphorus especially during fruit set and development (Figs 1& 2). Rambutan fruit requires macro-nutrients in the following order: N>K>Ca>Mg>P as indicated by the magnitude of their m-DRIS indices. The more regular the m-DRIS index the more deficient is the macro-element Thus a fertiliser schedule of 4-5 times a year is recommended as shown in Table 7. The end of harvest application in December-February can be split into two if the rain is intensive and prolonged. The application during fruit development can also be split into two if the flowering and fruiting is protracted. It is imperative that trees be irrigated shortly after the fertiliser has been applied to facilitate plant uptake and to obviate losses from leaching, run-off and volatilisation.

Table 7. Frequency of fertiliser application.

Frequency	Months	Proportion % of amount/year
4 (following late fruiting previous season)	January /February April/May July August/September	30 20 25 25
5 (following early fruiting previous season)	December/January March/April May/June August September/October	30 20 20 15 15

Organic fertiliser application

Organic fertilisers such as animal manure should only be used as supplements as one has to use large amounts to equate to the inorganic fertilisers as they are very low in macro-elements. Growers are encouraged to use them to improve soil structure, water holding capacity as well as soil fertility. One guideline is shown in Table 8.

Table 8. Schedule and rates for chicken manure fertiliser.

Tree age Year	Amount kg/tree/year	Freq/ year	Dynamic Lifter (g)				Common chicken manure (g)			
			N (4%)	P (3%)	K (1%)	Ca (7%)	N (5%)	P (2%)	K (1%)	Ca (3%)
3	2	1	80	90	20	140	150	40	20	90
4	4	1	160	120	40	280	200	80	40	120
5	5	2	200	150	50	350	250	100	50	150
6	6	2	240	180	60	420	300	120	60	180
7	8	2	320	240	80	560	400	160	80	240
8	10	2/3	400	300	100	700	500	200	100	300
9	10	2/3	400	300	100	700	500	200	100	300

Liming, calcium and magnesium replenishment

For rambutan, the optimum pH range is between pH 5.5 to pH 6.5 and soils with lower pH levels have to be limed to raise the pH level. The usual practice is to lime the soil to raise soil pH with dolomite, dolomite and lime, or dolomite and gypsum. Gypsum has a negligible effect on pH change but can correct for both sulphur and calcium deficiency. Lime alone is very effective in raising the pH but supplies only Ca. Dolomite which contains 15-22% Ca and 8-20% Mg, depending on the source, supplies both Ca and Mg and is also effective in raising soil pH. The actual amount of lime or dolomite to use to correct the pH depends on the soil type, soil pH and chemical source. For example, to raise the pH from < 5 to 6 may require up to 5 tons/ha of lime or dolomite. Liming is recommended once a year for rambutan as most soils are low in calcium and this may be done in Jan/Feb or May/Jun. We reiterate again here that the

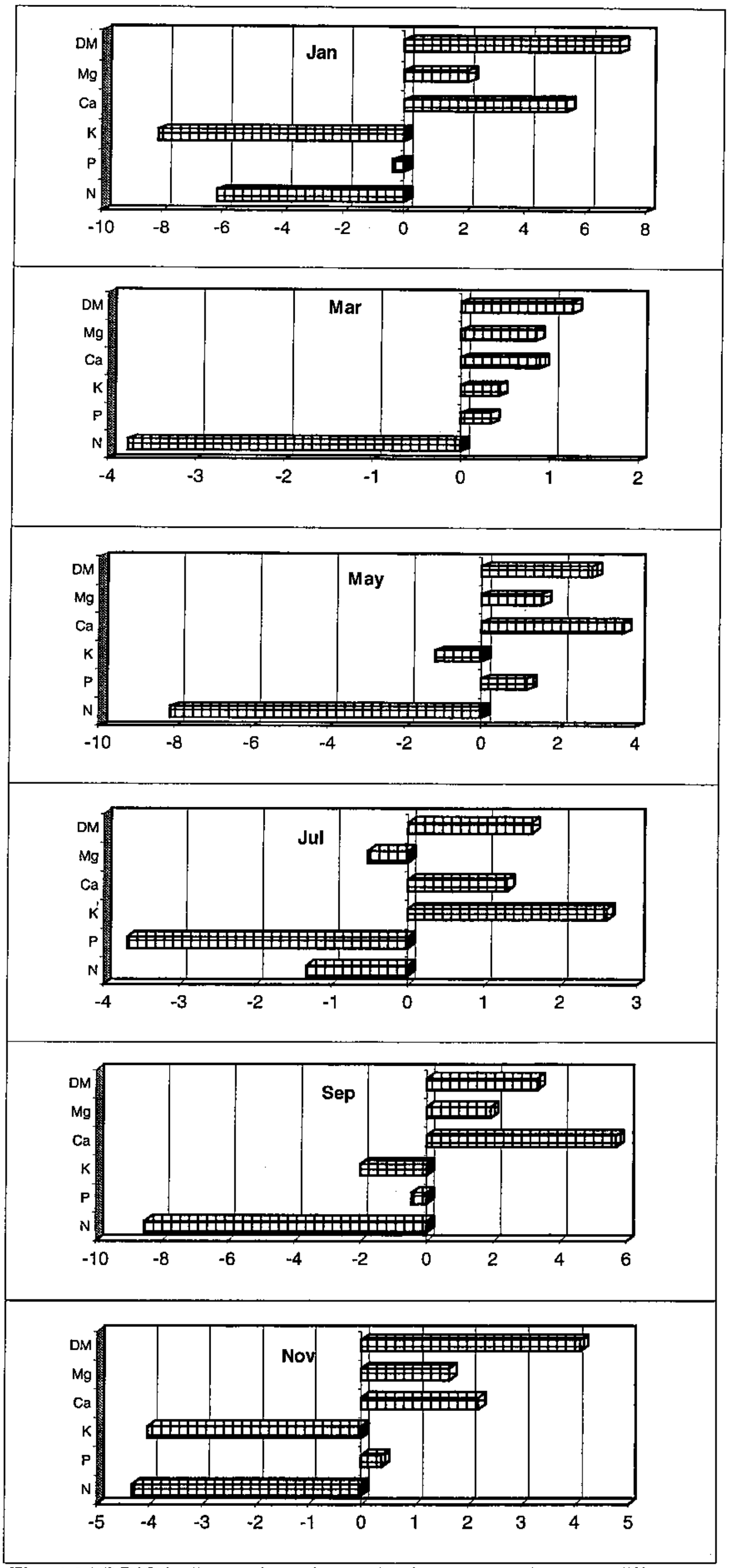

Fig. 1 M-DRIS indices of rambutan leaf macronutrients at different months

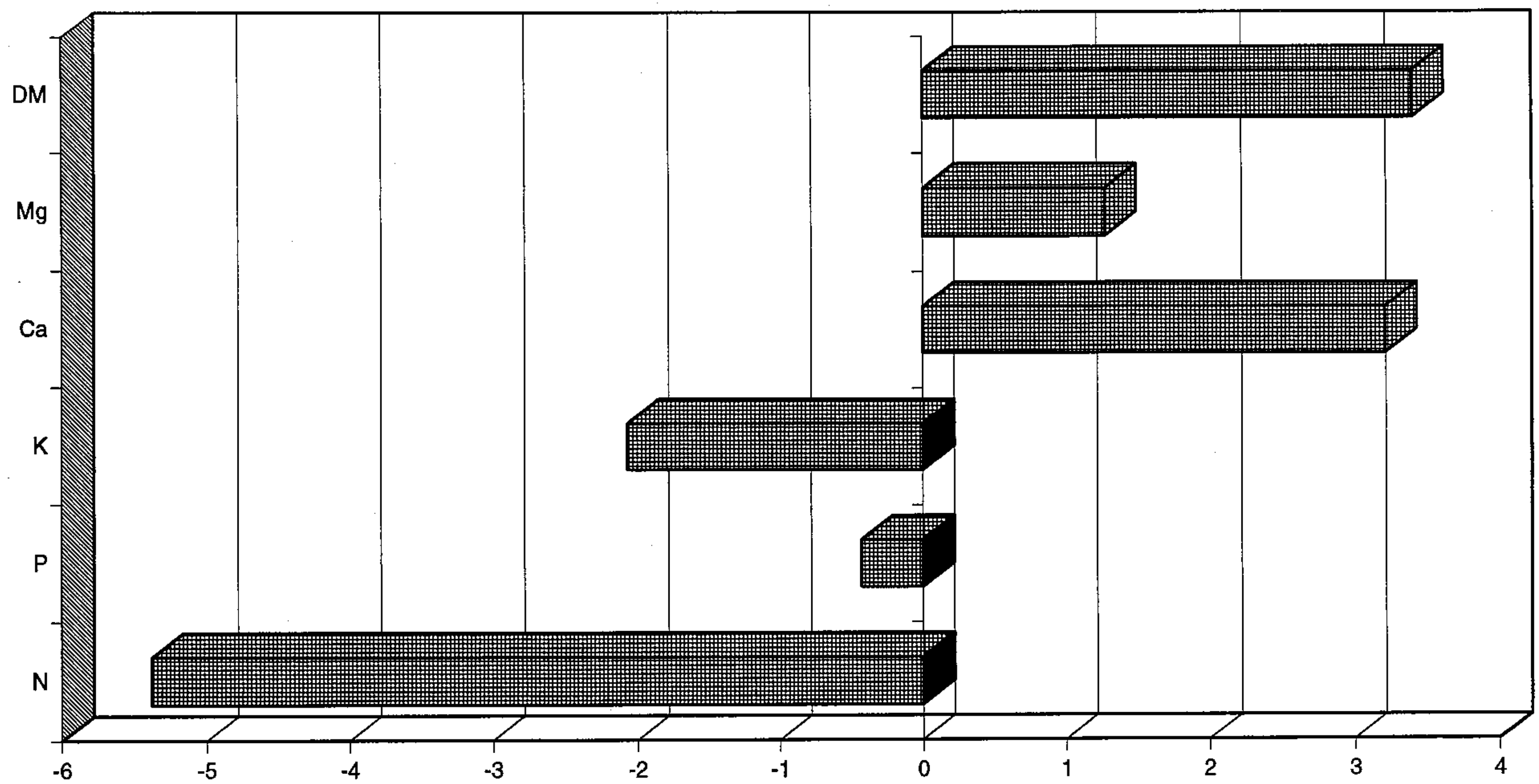

Fig.2 M-DRIS indices of rambutan leaf macronutrients 1992-1995

rambutan orchards around Darwin tend to have a low Ca:Mg ratio which ideally should be around 6. Thus for rambutan, lime or calcium sulphate is more preferable than dolomite. Calcium deficiency is common on acid soil of low pH which fixes calcium making it unavailable and also in soil with high nitrogen or phosphorus. Calcium deficiency can also be easily corrected by foliar sprays of calcium nitrate (5-15 g/L) or calcium chelate (2-3 g/L). Such calcium compounds should never be used with sulphate salts of other elements as this will result in precipitation of the insoluble calcium sulphate. When both calcium and magnesium need to be replenished, the amount of dolomite that has to be used can be obtained from the following table.

Table 9. Application rates of dolomite fertiliser.

Tree age	year	3	4	5	6	7	8	9	10
Yield	kg/tree/year	10	15	20	30	40	50	60	75
Ca removed	in g	8.91	13.37	17.82	26.73	35.64	44.55	53.46	66.83
Mg removed	in g	4.00	5.99	7.99	11.99	15.98	19.98	23.98	29.97
Dolomite	amount g/tree	300	400	500	600	700	800	900	1000
Ca 15 %	Ca (g) supplied	45	60	75	90	105	120	135	150
Mg 8%	Mg (g) supplied	24	32	40	48	56	64	72	80
Dolomite	amount (g)	300	400	500	600	700	800	900	1000
Ca 15 %	Ca (g) supplied	45	60	75	90	105	120	135	150
Mg 20%	Mg (g) supplied	60	80	100	120	140	160	180	200
Dolomite	amount (g)	250	350	450	550	650	750	850	950
Ca 22%	Ca (g) supplied	55	77	99	121	143	165	187	209
Mg 8%	Mg (g) supplied	20	28	36	44	52	60	68	76
Dolomite	amount (g)	250	350	450	500	600	700	800	900
Ca g (22%)	Ca (g) supplied	55	77	99	110	132	154	176	198
Mg g (20%)	Mg (g) supplied	50	70	90	100	120	140	160	180

Micro-nutrient fertilisation

Fruit trees require these micro-elements in very sparing quantities. Deficiencies of micro-nutrients are easily detectable by visual qualitative symptoms. Rambutan in the NT usually suffer from deficiencies of zinc, iron and boron and sometimes manganese. Deficiencies of these elements can be corrected by foliar sprays or soil application. For foliar applications, sprays are timed to coincide with the appearance of new vegetative flushes, ie. in January/February, March/April and May/June. Soil application can be administered via soil drenching or fertigation. In cases of acute deficiencies, 2-3 consecutive sprays 10-14 days apart may be necessary. A small quantity of a wetting agent or a small amount of 0.5-1 % urea (low in biuret) can be added to aid absorption by the foliage.

Zinc

Zinc deficiency is common on calcareous soils with pH > 6, acid leached soils, coarse sands, high organic soils or soils low in organic matter and heavily limed soils. On sandy acid soils liming can induce Zn deficiency. Zinc is variably mobile in plants and deficiency symptoms take the form of little leaf, rosette terminal formation, or chlorotic mottles in less severe cases. Zinc deficiency can be corrected by using zinc chelate or zinc sulphate heptahydrate at 2 g/L spray, or the latter at 7-8 g/m^2 soil application or zinc oxide soil application at 5 g/m^2.

Iron

Iron is rather abundant in many soils but often in a form unavailable to the plant. Iron deficiency is induced when there is too high soil water and low soil temperature. High pH or free calcium carbonate induces iron chlorosis despite adequate iron levels in the plant. Deficiency appears as interveinal chlorosis and in severe cases bleaching of young foliage followed by necrosis. Iron deficiency can be overcome by using iron chelate at 1 g/L spray or 2-3 g/m^2 soil applied or 3-5 g/L ferrous sulphate spray. On calcareous soils or high pH soils avoid soil application.

Manganese

Manganese deficiency is especially evident on light sandy soils. Low organic matter affects its availability, a high soil pH greater than pH 6.5 decreases its availability. High calcium or magnesium interferes with its uptake and low sulphur makes its less available to the plant. Diagnostic symptoms consist of interveinal chlorosis becoming necrotic with time and new growth is affected first as the element is rather immobile. Manganese deficiency can be ameliorated by spray applications of manganese sulphate at 2 g/L or manganese chelate at 1 g/L.

Boron

Boron aids in the movement of Ca in plants and also helps in the accumulation of sugars and starches. It is necessary for pollen germination, flower and fruit development. The element is rather immobile in plants. Deficiency occurs when the plant is expanding rapidly during flowering, fruiting or during periods of drought. Obvious symptoms include death of growing points, incomplete development of fruits, deformed fruits and reduced plant quality. B is deficient in high pH soils or heavily limed soils. Too high levels of NPK also induce B deficiency. B is greatly leached in light textured sandy soils, acid soils or soils low in organic matter. Deficiency can be corrected by using borax or Solubor®. Borax is not compatible with other chemical sprays and is use on its own as 1-3 g/L sprays or 2-3g/m^2 soil application. Solubor® is more compatible and can be used at 0.5-2 g/L sprays but avoid mixing with zinc sulphate which results in precipitation of the insoluble salt. Solubor® is compatible with calcium nitrate or calcium chloride sprays, liquid NPK fertiliser eg. ammonium nitrate, urea, diammonium phosphate and potassium chloride. Solubor® is only compatible with manganese sulphate at low rates.

Copper

Copper deficiency characterised by curling, wilting and death of young shoots is not common on rambutan because of sprays of protective copper containing fungicides used at rates of 5-10 g/L for control of diseases in rambutan. Copper is absorbed by leaves but copper translocation in plants is poor due to the low mobility of copper.

Molybdenum

Molybdenum deficiency characterised by paling and yellowing of leaves is not common in rambutan. It can occur on soils rich in iron and aluminium, or in acid soils below pH 5. Deficiency can be corrected by liming such soil or by sprays of sodium molybdate at 1 g/L.

Sources and composition of chemical fertilisers

The sources of fertilisers supplying macro- and micro-nutrients used for ground application and fertigation are shown in Tables 11 & 12. The chemical formulae, chemical composition and practical solubility at 25°C are listed.

Fertigation

Fertilisers can be applied through the irrigation system. This process is commonly referred to as "fertigation". Soluble forms of commonly available fertilisers are selected or special proprietary soluble/liquid fertiliser mixes can be used. Fertigation has a number of advantages and disadvantages compared to adding granular fertilisers. The advantages are:

- nutrients can be applied in small amounts regularly as the tree requires them.
- this leads to increased fertiliser use efficiency and sometimes an improvement in yield.
- nutrients are applied directly to the root system within the wetted area ensuring minimum losses.
- leaching losses after rain are minimised due to split applications.
- labour and machinery costs are reduced as fertilisers do not have to be supplied individually to each tree.

- well designed injection equipment can be convenient to use and lends itself to automation.

Some of the disadvantages of fertigation are:

- up front capital cost of fertigation equipment.
- soluble grades of fertiliser are often more expensive than granular fertilisers.
- require the ability to calculate fertiliser mix based on solubility of fertiliser and nutrient requirements.
- become reliant on equipment which needs to be well maintained and may fail at times.
- need to pay attention to storing, handling and mixing of fertilisers.
- irrigation is still required to apply fertilisers during the wet season.

There are no tried and tested fertigation recipes for rambutan, however, a schedule can be calculated based on the granular fertiliser program. A regular soil and leaf nutrient monitoring program will allow modifications to be made. If fertigating then the frequency of application should be increased to 10-12 times per year. A simple application schedule could be as presented in Table 10.

Table 10. Schedule for fertigating rambutan

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Application	1	2	1	1			1#	1	1	1	1	1

apply when greater than 50% of trees are in flower

Fertiliser selection for fertigation

Nitrogen (N)

Commonly used forms of nitrogen in fertigation are: ammonium nitrate, ammonium sulphate, urea and calcium nitrate. Ammonium sulphate is very acidifying and urea is mildly acidifying. Hence, care must be taken to ensure the soil pH balance is not altered.

Phosphorous (P)

When fertigating it is essential that fertilisers which contain P are not mixed with fertilisers containing calcium (Ca) as a precipitate will form. Phosphorous will also form insoluble compounds with other chemicals, so care should be taken when injecting P. In fact it is often best to inject P by itself. Common forms of P for fertigation are: phosphoric acid (liquid available in two concentrations) and irrigation grades of diammonium phosphate (DAP) and monoammonium phosphate (MAP).

Potassium (K)

Fertilisers containing K used for fertigation include: potassium sulphate (sulphate of potash), potassium nitrate and potassium chloride (muriate of potash). Potassium chloride should not be used for fertilising rambutans, despite the fact that it is a good, soluble and cheap source of K, as rambutan is extremely sensitive to chlorides.

Calcium (Ca)

The major calcium source used in fertigation is calcium nitrate. It is an expensive fertiliser. It is recommended that Ca fertiliser be injected separately due to potential precipitation problems. The Ca requirements of rambutans are easily satisfied by liming, hence injectable sources of Ca should not be required by most growers.

Micro-nutrients

Micro-nutrients such as zinc, iron, manganese, magnesium, boron and molybdenum can be applied via fertigation. The amounts to be applied are usually small and care needs to be taken to accurately weigh the ingredients. Many commonly used fertilisers (Tables 11 & 12) which supply essential macro- and micro- nutrients are suitable for fertigation.

Fertigation equipment

For fertigation to be successful the irrigation system must be well designed. This should, of course, be so in any case because efficient irrigation management of rambutans also requires that all the trees in an irrigation block are receiving the same amount of water per irrigation. There are four main methods of injecting fertilisers: pumps (electric or hydraulic), pressure differential systems, vacuum (venturi) systems and suction systems. The method you choose will depend on how you wish to manage the system. Pump systems offer the most control and can be set up to inject fertiliser proportionally or a set quantity in a given amount of time. Examples of pump systems include hydraulically driven pumps such as Dosatron, TMB and AMIAD or electrical pumps such as the Prominent metering pump, centrifugal, piston, diaphragm, gear, and helical rotor pumps. The important part of pumping systems is that the pressure at the injection point must be higher than the irrigation system pressure.

Table 11. Chemical composition and solubility of fertilisers sources supplying macro-nutrients.

Source of fertiliser	Chemical formula	% N/P/K/Ca/Mg/S	Practical solubility (kg/100L) at 25°C
Nitrogen N			
Urea	$CO(NH_2)_2$	45	78
Ammonium nitrate	$NH_4\ NO_3$	33.5 - 34	100
Ammonium sulphate	$(NH_4)_2\ SO_4$	20	71
Aqua ammonium	$NH_3 + H_2O$	20-24	
Ammonium phosphate	$NH_4\ H_2PO_4$	10-11	23
Ammonium nitrate of lime	$NH_4\ NO_3 + CaCO_3$	20.5	
Ammonium polyphosphate dry form	$NH_4H_2PO_4 + (NH_4)_3HP_2O_7$	10	
liquid form		15	
Di ammonium phosphate	$(NH_4)_2\ HPO_4$	18	43
Potassium nitrate	KNO_3	13	
Calcium nitrate	$CaNO_3$	15.5	
Sodium nitrate	$NaNO_3$	16	
Phosphorus P			
Monosuperphosphate	$Ca(H_2PO_4)_2 + CaSO_4$	8.8	
Triple superphosphate	$Ca(H_2PO_4)_2$	19.8	
Monoammonium phosphate	$NH_4\ H_2PO_4$	21.1	23
Diammonium phosphate	$(NH_4)_2HPO_4$	20.2	43
Ammonium polyphosphate dry form	$NH_4H_2PO_4 + (NH_4)_3HP_2O_7$	15	
liquid form		27.3	
Phosphoric acid - 60%		19	liquid
Phosphoric acid - 85%		26.8	liquid
Potassium K			
Muriate of potash (Potassium chloride)	KCl	49.8	30 (not for rambutan)
Potassium sulphate	K_2SO_4	41.5	10
Potassium nitrate	KNO_3	36.5	31
Calcium Ca			
Dolomite	$CaCO_3 + MgCO_3$	15-22	
Gypsum	$CaSO_4$	22	
Calcite	$CaCO_3$	40	
Lime 90% pure	$CaCO_3$	36	
Slaked Lime	$Ca(OH)_2$	54	
Monosuperphosphate	$Ca(HPO_4)_2 + CaSO_4$	20	
Triple superphosphate	$Ca(H_2PO_4)_2$	14	
Calcium nitrate	$CaNO_3$	19	60
Magnesium Mg			
Dolomite	$CaCO_3 + MgCO_3$	8-20	
Epsom salt (Magnesium sulphate)	$MgSO_4.7H_2O$	10	71
Kieserite	$MgSO_4.H_2O$	18	
Potassium magnesium sulphate	$K_2SO_4.2MgSO_4$	11	
Sulphur S			
Ammonium sulphate	$(NH_4)_2SO_4$	24	71
Potassium sulphate	K_2SO_4	18	10
Potassium magnesium sulphate	$K_2SO_4.2MgSO_4$	23	
Epsom salt	$MgSO_4.7H_2O$	14	71
Monosuperphosphate	$Ca(H_2PO_4)_2 + CaSO_4$	14	
Gypsum (Calcium sulphate)	$CaSO_4.\ 2H_2O$	17	
Elemental sulphur	S	88-100	

Table 12. Chemical composition and solubility of fertiliser sources supplying micro-nutrients.

Source of fertiliser	Chemical formula	% element*	Practical solubility (kg/100L) at 25°C**
Boron B			
Borax	$Na_2B_4O_7.10H_2O$	11	
Boric acid	H_3BO_3	17	
Sodium pentaborate	$Na_2B_{10}O_{16}.10H_2O$	18	
Sodium tetraborate			56
Fertiliser borate 46	$Na_2B_4O_7.5H_2O$	14	
Fertiliser borate 65	$Na_2B_4O_7$	20	
Solubor®	$Na_2B_{10}O_{16}.10\ H_2O$	20	22
Copper			
Copper sulphate	$CuSO_4.3Cu(OH)_2$	13-53	
Cuprous oxide	Cu_2O	89	
Cupric oxide	CuO	75	
Copper acetate	$Cu(C_2H_3O_2)_2.\ H_2O$	32	
Copper oxalate	$Cu\ C_2O_4.1/2H_2O$	40	
Copper chelate	$Na_2CuEDTA$	13	
Copper ammonium phosphate	$Cu(NH_4)PO_4.H_2O$	32	
Manganese Mn			
Manganese sulphate	$MnSO_4.3H_2O$	26-28	105
Manganese oxide	MnO	41-68	
Manganese carbonate	$MnCO_3$	31	
Manganese chloride	$MnCl_2$	17	
Manganese oxide	MnO_2	63	
Manganese chelate	MnEDTA	12	
Zinc Zn			
Zinc sulphate	$Zn\ SO_4.\ H_2O$	36	22
Zinc oxide	ZnO	78	
Zinc carbonate	$ZnCO_3$	56	
Zinc chelate	$Na_2ZnEDTA$	14	
Iron Fe			
Ferrous sulphate	$FeSO_4$	36.77	
Sodium iron edetate (Iron chelate)	NaFeEDTA	15.22	29
Molybdenum Mo			
Ammonium molybdate	$(NH_4)_6Mo_7O_{24}.2H_2O$	54	
Molybdenum trioxide	MoO_3	66	
Sodium molybdate	$Na_2MoO_4.2H_2O$	39	56
Chlorine Cl (not for rambutan)			
Ammonium chloride	NH_4Cl	66	
Calcium chloride	$CaCl_2$	65	
Magnesium chloride	$MgCl_2$	74	
Muriate of potash (potassium chloride)	KCl	47	30
Sodium chloride	NaCl	60	

* Dohanue *et al.*, 1990. ** Nakayama and Bucks, 1986

Formulation of a fertigation mix (Table 13)

Assumptions:

Tree age = 10 years

Number of trees in a irrigation block = 200

Sprinkler flow rate = 90 L/hr

Total flow rate = 18000 L/hr

Canopy ground area per tree = $38m^2$

Table 13. Fertigation injection requirements for 10 year old rambutan trees based on rates in Table 6.

Macro-element/micro-nutrient fertiliser	Annual requirement	kg/200 trees/year	kg per injection
Macro-element			
Nitrogen	550 g/tree/year	110	10
Phosphorous	275 g/tree/year	55	5
Potassium	495 g/tree/year	99	9
Micro-nutrient fertiliser			
Zinc sulphate	7 g/m^2/year, zinc sulphate	53	4.8
Iron chelate	2.5 g/m^2/year iron chelate	19	1.727
Manganese sulphate	1.0 g/m^2/year manganese sulphate	7.6	0.69
Solubor®	1.0 g/m^2/year, Solubor	7.6	0.69
Sodium molybdate	0.1 g/m^2/year, sodium molybdate	0.76	0.69

Ideally, the above fertilisers should be added in three separate lots of 200 L of water per injection period to avoid any incompatibility problems. Mix 1 can include N, P and K. Mix 2 can include Zn, Fe, Mn and Mo and Mix 3 would be B by itself. Note the following mixes are examples only. If you wish to use other fertilisers do so after consulting with DPIF Horticulture or your fertiliser supply representative.

Calculation of the above major ingredients

Mix 1

Step 1

N = 10 kg, P = 5 kg and K = 9 kg

Calculate the P requirement using MAP from information in Table 13

MAP = 12% N and 27% P

Therefore to apply 5 kg of P per injection you will require

5 x 100/27 kg = 18.5 Kg of MAP

The amount of N in the 18.5 kg of MAP has to be calculated

N = 18.5/100 x 12 = 2.2 kg

Step 2

Next calculate the K requirement using 2/3 potassium nitrate (KNO_3) and 1/3 potassium sulphate (K_2SO_4). Therefore the 6.0 kg of the K requirement will be supplied by KNO_3 and 3.0 kg by K_2SO_4.

KNO_3 = 6/39 x 100 = 15.4 kg

The amount of N in the above amount of KNO_3 is

N = 15.4/100 x 14 = 2.16 kg

K_2SO_4 =3/41 x 100 = 7.32 kg

The amount of S in the above amount of K_2SO_4 is

S = 7.32/100 x 18 = 1.32 kg

Step 3

Calculate the remaining N requirement using urea

Total N required = 10 kg, N supplied by MAP = 2.2 kg, N supplied by KNO_3 = 2.16 kg.

Remaining N required = 10 - 2.2 -2.16 = 5.64 kg.

Urea = 5.64/46 x 100 = 12.26 kg

Therefore Mix 1 will be made up of:

18.5 kg MAP, 23.1 kg KNO_3 7.32 kg K_2SO_4, 12.26 kg Urea

The least soluble of the above is K_2SO_4 (10 kg/100 L). At least 200 litres should be used to dissolve the mix. It is advisable to check the solubility of fertiliser mixes by using a jar or bucket test. Mix the proportional amounts of fertiliser in 1.0 or 5.0 litres of water and check for any solubility problems.

Mix 2

Mix 2 consists of 4.8 kg zinc sulphate, 1.73 kg iron chelate, 0.69 kg manganese sulphate and 0.069 kg sodium molybdate. The above micronutrients are all highly soluble. However, given that they are being mixed and need to be distributed evenly over the 200 trees, it would be advisable to dissolve them in the maximum amount of water (200 L).

Mix 3

Mix 3 comprises 0.69 kg Solubor® on its own. Solubor® is very soluble, however to ensure as even distribution as possible it should also be mixed with the maximum amount of water (200 L).

Fertigation injection time

Injection times depend on the injection rate of the pump, the volume of liquid to be injected, the normal run time of the irrigation system and the distance from the injection point to the orchard. Normally fertilisers are injected in the middle half of the irrigation cycle with sufficient time given to fill and flush the system. Travel times can be a calculated by adding the travel time through each pipe segment. For each pipe size the calculation is:

Time = Distance/Velocity = Distance x Inside area of pipe/Flow rate through pipe

Distance = metres

Pipe area = sq metres

Flow rate = cubic metres/second

Time = seconds

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Rambutan Nutrient Requirement and Management

TK Lim, L. Luders, Y. Diczbalis and M. Poffley

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SUSTAINABLE AGRICULTURE

THE DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES IS COMMITTED TO THE PRINCIPLES AND PRACTICES OF SUSTAINABLE AGRICULTURE

Definition:

Sustainable agriculture is the use of practices and systems which maintain or enhance:

- the economic viability of agricultural production:
- the natural resource base: and
- other ecosystems which are influenced by agricultural activities.

Principles:

1. Agricultural productivity is sustained or enhanced over the long term.
2. Adverse impacts on the natural resource base of agricultural and associated ecosystems are ameliorated, minimised or avoided.
3. Harmful residues resulting from the use of chemicals for agriculture are minimised.
4. The nett social benefit (in both dollar and non-dollar terms) derived from agriculture is maximised.
5. Agricultural systems are sufficiently flexible to manage risks associated with the vagaries of climate and markets.

SUSTAINABLE AGRICULTURE IN THE NORTHERN TERRITORY

Introduction

The establishment of fertiliser recommendations for fruit trees must be based on rational interpretation of sound plant and soil analyses taking into account the crop phenology, crop nutrient removal, leaf nutrient status, crop yield, nutrient recycling, soil type and characteristics, meteorological conditions and sources of fertilisers used. For perennial fruit trees soil analyses alone are not as useful as plant analysis in rationalising the fruit nutrient requirement, thus both are required. Beside fertiliser recommendation, plant analysis is an indispensable tool for a) the diagnosis and treatment of plant nutrient deficiencies, imbalances and toxicities; b) monitoring the efficacy of current fertiliser practices; c) establishing optimum levels of nutrient in plants; d) assessing the removal of key elements by the crop; and e) predicting and allowing for manipulation of crop yield and quality to a certain extent.

Interpretation of plant analysis

Various approaches have been used in the interpretation of plant analysis. The traditional method of leaf nutrient interpretations using critical nutrient concentrations (critical values) or sufficiency range do not account for the dynamic nature of foliar nutrient composition influenced by the physiological stage of crop growth, nutrient interactions and interactions between nutrients, dry matter accumulation and metabolic activities. A critical value is the concentration of nutrient in a particular plant part sampled at a particular growth stage at which a 5-10% reduction in yield is observed. Meeting the requirement that plant tissues be sampled at a particular stage is not always convenient. Sufficiency ranges have been proposed such that the lower limit represents roughly the critical level and the upper limit is set at a value corresponding to unusually high concentration. Contrary to giving flexibility to diagnoses they lead to decrease in diagnostic precision because the limits are far too wide. To overcome such limitations the Diagnosis and Recommendation Integrated System (m-DRIS) method was evolved by Beaufils in 1973 and has since undergone considerable modifications. The m-DRIS method in its various modified versions has been successfully developed as a reliable diagnostic tool and applied to many annuals and perennial crops including fruit trees. The m-DRIS approach minimises the effect of physiological age of tissue enabling sampling of wider tissue age than is permissible under the critical value method. It considers nutrient interactions and other factors and computes nutrient balance indices in order of limitations as being negative (deficient), positive as excess and zero as balance using nutrient ratios.

Leaf and soil sampling

A sound leaf analysis interpretation is dependent on a good uniform plant sampling procedure. Young immature leaf tissues are generally the most sensitive for immobile elements like Ca and B while older leaf tissues more sensitive for the phloem-mobile elements like N, P, K, Mg and the other micro-nutrients. We standardised the method as follows: taking the middle leaflet pair of the latest mature green (RHS green group 140 C,) vegetative flush ie. the third and fourth leaves from the shoot terminal (Table 1). This is the best leaf age to sample as most leaf nutrients levels except for calcium and boron are comparatively the least variable with the lowest coefficients of variability *circa* 20%. Ten to 20 random leaflet sub-samples from 4 quadrats of the tree are then bulked. However, for diagnosis of Ca or B deficiency the immature light green (RHS green group 140A) should be taken. At the same time, 4 soil cores 15-20 cm deep, should be taken from each tree and bulked for soil analysis. The number of samples to take depends on the size of the block eg. 4 final leaf samples and soil samples for an average 20 ha block. The best sampling time for leaf analysis is when most leaf nutrients levels are comparatively the most stable and with the lowest coefficients of variability *circa* 20%. For rambutan in the Darwin region our studies indicate that this occurs in May/June, ie. just before flowering (Table 2).

Rambutan leaf nutrient norms - sufficiency range and m-DRIS norms and ratios

The mean nutrient levels in rambutan leaves, the sufficiency range for the nutrients and the m-DRIS norms for the individual elements and ratios are shown in Table 3. These have been computed from 4 years of nutrient logging at bimonthly intervals of 7 rambutan orchards involving more than 500 samples. The sufficiency range standards are established by taking the 95% confidence interval about the mean percent concentration of nutrients at May/June sampling period.

Rambutan soil nutrient status

Rambutan is grown mainly on the red and yellow brown earths or kandosols in the NT. The mean soil properties of the rambutan orchard in the NT computed from more than 500 samples taken over 4 years from 7 rambutan orchards are shown in Table 4. The mean pH level of 6.27 is within the optimum range of pH 5.5-6.5. The orchards around Darwin tend to have a low

Table 1. Variability in rambutan leaf nutrient status at different physiological stages (recommended stage shown in bold).

Leaf stage		N	P	K	Ca	Mg	S	Cl	Cu	Zn	Mn	Fe	B	Na
Light green (Green group 140A)	Mean	1.668	0.342	1.218	0.187	0.132	0.133	0.028	9.333	25.500	103.333	46.167	20.333	0.004
	SD	0.540	0.059	0.144	0.034	0.026	0.027	0.017	2.160	3.937	27.245	10.998	1.751	0.001
	CV	32.369	17.307	11.831	18.454	20.046	19.937	60.791	23.146	15.439	26.366	23.823	8.612	14.084
Green (Green group 140B)	Mean	1.860	0.320	1.000	0.593	0.272	0.200	0.043	8.500	94.667	448.000	222.167	56.000	0.010
	SD	0.225	0.080	0.154	0.397	0.123	0.023	0.010	1.378	40.053	216.891	76.690	15.672	0.005
	CV	12.089	24.922	15.375	66.982	45.108	11.402	23.834	16.217	42.310	48.413	34.519	27.985	52.416
Mature green (Green group 140C)	**Mean**	**1.618**	**0.328**	**0.767**	**0.828**	**0.322**	**0.240**	**0.053**	**5.833**	**119.833**	**618.000**	**281.333**	**80.333**	**0.012**
	SD	**0.208**	**0.064**	**0.104**	**0.385**	**0.074**	**0.042**	**0.019**	**0.983**	**20.808**	**253.077**	**52.481**	**8.937**	**0.004**
	CV	**12.828**	**19.589**	**13.572**	**46.528**	**23.132**	**17.678**	**34.911**	**16.855**	**17.364**	**40.951**	**18.654**	**11.125**	**34.993**

Table 2. Variability in rambutan leaf nutrient levels at different sampling times (recommended sampling time shown in bold).

		N	P	K	Ca	Mg	Na	Cl	S	Cu	Zn	Mn	Fe	B
Jan	Mean	1.54	0.20	0.62	0.70	0.42	0.038	0.06	0.15	8.58	27.14	124.60	50.93	49.25
	SD	0.30	0.04	0.19	0.27	0.17	0.054	0.04	0.02	5.84	23.08	123.02	37.98	20.61
	CV	19.29	22.32	31.10	38.96	41.52	142.144	67.95	13.48	68.08	85.07	98.72	74.58	41.86
Mar	Mean	1.77	0.23	0.83	0.68	0.43	0.011	0.05	0.16	11.69	25.59	121.61	49.79	38.09
	SD	0.32	0.05	0.27	0.22	0.18	0.010	0.03	0.02	13.09	19.86	103.38	40.58	23.16
	CV	18.05	21.13	32.13	32.11	41.62	98.413	60.17	14.04	111.96	77.63	85.01	81.50	60.79
May	**Mean**	**1.69**	**0.23**	**0.76**	**0.68**	**0.43**	**0.01**	**0.06**	**0.17**	**14.94**	**42.25**	**125.67**	**82.74**	**55.94**
	SD	**0.31**	**0.05**	**0.18**	**0.21**	**0.17**	**0.01**	**0.05**	**0.02**	**20.82**	**25.25**	**105.40**	**46.71**	**24.70**
	CV	**18.41**	**21.46**	**23.96**	**30.80**	**38.93**	**52.65**	**89.37**	**13.21**	**139.35**	**59.76**	**83.87**	**56.45**	**44.16**
Jul	Mean	1.83	0.21	0.86	0.67	0.42	0.02	0.10	0.16	27.44	48.46	163.09	95.81	53.04
	SD	0.31	0.05	0.21	0.22	0.17	0.02	0.08	0.03	33.43	28.76	142.13	57.07	23.17
	CV	16.80	23.52	24.09	32.11	40.17	132.40	79.28	19.48	121.85	59.35	87.15	59.57	43.68
Sep	Mean	1.58	0.21	0.73	0.72	0.43	0.02	0.13	0.16	22.39	48.12	130.62	92.20	49.27
	SD	0.31	0.05	0.19	0.22	0.16	0.01	0.11	0.02	26.85	31.25	108.55	54.90	16.77
	CV	19.75	23.46	25.52	30.09	36.39	51.04	81.36	13.96	119.94	64.94	83.10	59.54	34.03
Nov	Mean	1.64	0.22	0.70	0.67	0.42	0.02	0.08	0.16	12.77	31.06	103.91	54.48	41.11
	SD	0.27	0.05	0.20	0.24	0.17	0.02	0.07	0.02	15.98	26.90	99.85	43.82	10.98
	CV	16.59	22.30	28.77	36.11	39.95	105.35	85.34	15.35	125.16	86.62	96.09	80.44	26.71

Ca:Mg ratio (~ 2) which ideally should be around 6. This means that more calcium is needed in most orchards. The K:Mg ratio and the C:N ratio is close to the optimum 0.5. and 20:1 respectively for these soils. However, the high standard deviation of the K:Mg ratio indicates wide variability of these elements among the orchard soils. The C:S ratio is way above 400:1 indicating that sulphur is being immobilised and has to be replenished by using sulphur fertilisers. One suggestion is to use calcium sulphate to rectify both calcium and sulphur levels. Also soils low in sulphate tend to increase uptake of chlorine when it is available and rambutan is sensitive to high chlorine levels.

Fertiliser grade, ratio and formulation

Fertilisers are usually expressed in terms of mineral nutrient grades of 3-4 of the significant macro-elements. Fertiliser grade is the minimum guaranteed percentage of plant nutrients in a fertiliser. Two general ways are used to express these grades:

i) an oxide basis eg. N: P_2O_5: K_2O or N: P_2O_5: K_2O

ii) an elemental basis eg. N:P:K or N:P:K:Mg.

The latter is more universally used and is most widely accepted. To convert the oxide to the elemental basis and vice-versa the following equations can be used:

P_2O_5 x0.44 = P, K_2O x 0.83 = K MgO x 0.6 = Mg

P x 2.29 = P_2O_5 K x 1.20 = K_2O Mg x 1.667 = MgO

For example the common NPKMg fertiliser for fruiting trees expressed as 12:12:17:2 on an oxide basis is 12:5:14:1.2 on an elemental basis and means that the fertiliser contains 12% total N, 5% available P, 14% K and 1.2% Mg.

The ratio of a fertiliser refers to the proportion of one plant nutrient percentage to another. for example a 10:10:10 NPK fertiliser has equal percentages of N, P, and K and has a ratio of 1:1:1. Formulation refers to the amounts of the various sources of plant nutrient materials used in the fertiliser.

Rambutan nutrient removal

Studies here and elsewhere have shown that rambutan removes a lot of N and K from fruits and harvested twigs. In rambutan fruit the sequence of nutrient removal is as follows: N>K>Ca>Mg>P. Our crop nutrient monitoring studies show that rambutan requires more N

Table 3. Sufficiency range and m-DRIS norms of rambutan leaf nutrient levels for the NT.

Element/ ratio	Sufficiency range	m-DRIS norms
N %	1.54-1.68	1.67
P %	0.21-0.23	0.22
K %	0.69-0.77	0.75
Ca %	0.68-0.77	0.69
Mg %	0.41-0.48	0.42
Na %	0.01-0.02	0.02
Cl %	0.11-0.13	0.1
S %	0.16-0.17	0.16
Cu mg/kg	16-25	16.34
Zn mg/kg	43-54	37.20
Mn mg/kg	104-150	128.30
Fe mg/kg	77-98	71.17
B mg/kg	43-55	47.86
n/p		8.09
n/k		2.40
n/ca		2.77
n/mg		4.68
p/k		0.31
p/ca		0.35
p/mg		0.58
k/ca		1.28
k/mg		2.17
ca/mg		1.81

Table 4. Mean soil properties of rambutan orchard soils in the NT.

Soil property	Mean value	SD
Electrical conductivity mS/cm	0.05	0.04
pH	6.27	0.67
Total nitrogen %	0.1	0.04
Organic carbon %	2.08	4.49
C:N	23:1	75.65
HCO_3 mg/kg	155.07	112.92
Cl mg/kg	8.54	10.33
P mg/kg	63.3	61.17
S mg/kg	15.09	17.23
Zn mg/kg	2.84	2.61
Fe mg/kg	56.05	61.58
K cmol (+)/kg	0.97	0.5
Ca cmol(+)/kg	4.43	2.38
Mg cmol(+)/kg	3.32	2.31
CEC cmol(+)/kg	8.72	4.11
Ca:Mg	1.95:1	1.43
K:Mg	0.55:1	0.69

and K than P especially during fruit development (Fig. 1 & 2). For every 100 kg of fruit and 100 kg of twigs removed per hectare, the following amounts of macro-elements are removed:

Fruits = N - 199 g, P - 26.8 g, K - 152 g, Ca - 72 g, Mg - 36.78 g

Twigs = N - 256 g, P - 390 g, K - 240 g, Ca - 171 g, Mg - 32 g.

During harvest the weight of twigs harvested with the fruits is around 10% of the fruit weight harvested.

Table 5. Macro-nutrients removed by harvested rambutan fruit.

Tree age	Fruit Yield	Twigs harvested	Nutrients removed in g during fruit harvest				
year	kg/tree/year	kg	N	P	K	Ca	Mg
3	10	1	22.46	6.6	17.6	8.91	4.00
4	15	1.5	33.69	9.9	26.4	13.365	5.99
5	20	2	44.92	13.2	35.2	17.82	7.99
6	30	3	67.38	19.8	52.8	26.73	11.99
7	40	4	89.84	26.4	70.4	35.64	15.98
8	50	5	112.3	33	88	44.55	19.98
9	60	6	134.8	39.6	105.6	53.46	23.98
10	75	7.5	168.5	49.5	132	66.825	29.97

Fertiliser application rates

We have to replenish the amounts shown above as well as the amount of nutrients consumed for flower, fruit, root, leaf and twig/branch growth; nutrients removed by pruning branches: nutrients lost from leaching, run-off, volatilisation and immobilisation in the soil. Also, in general fertiliser usage, we have to account for the expected efficiencies which are approximately 30-70% of added N, 5-30% of added P, 50-80% for added K. Leaves do replenish some nutrients from recycling but the amount is not known for rambutan. A suggested schedule for rambutan is:

Planting hole

During planting, 200g superphosphate, 100 g dolomite and 1 kg well decomposed organic manure are thoroughly mixed with top soil in the planting hole.

Non-bearing tree

For a non-bearing tree, an NPK = 10:4:8 grade fertiliser applied 5-6 times for year 1 and 2 commencing 3 months after planting is recommended. The rates are:

year 1 0.5 kg/tree/year,

year 2 1 kg/tree/year.

Bearing trees

Using the current NPK fertiliser 11:8:12 grade for fruiting trees, comparatively much P is wasted. In fact the composition of all three elements can be reduced. The NPK granular fertiliser should be chloride free as rambutan is extremely sensitive to chloride levels higher than 0.018%. Chloride toxicity is usually characterised by chlorosis and necrosis near the leaf margin, tips and often accompanied by defoliation of young leaves. Adequate amount of chloride is provided by irrigation water and by chloride impurities in fertiliser mixtures.

One guideline is to use a N:P:K = 10:5:9 (chloride free) fertiliser for fruiting trees as follows:

Table 6. Fertiliser schedule for fruiting rambutan trees.

Tree age year	Yield kg/tree/year	Fertiliser kg/tree/year	Nutrients in g /tree/year N	P	K
3	10	2.0	200	100	180
4	15	2.5	250	125	225
5	20	3.0	300	150	270
6	30	3.5	350	175	315
7	40	4.0	400	200	360
8	50	4.5	450	225	405
9	60	5.0	500	250	450
10	75	5.5	550	275	495

The above quantities should be increased with increasing yield and age of trees. Also the quantities have to be adjusted according to leaf nutrient levels revealed by regular leaf and soil nutrient analyses and, if rambutan trees are heavily pruned for that year, more nutrients should be applied.

Timing and frequency of granular fertiliser application

Based on our crop phenological studies and analysis of the crop nutrient requirement using a modified DRIS technique, rambutan consumed more nitrogen and potassium than phosphorus especially during fruit set and development (Figs 1& 2). Rambutan fruit requires macro-nutrients in the following order: N>K>Ca>Mg>P as indicated by the magnitude of their m-DRIS indices. The more regular the m-DRIS index the more deficient is the macro-element Thus a fertiliser schedule of 4-5 times a year is recommended as shown in Table 7. The end of harvest application in December-February can be split into two if the rain is intensive and prolonged. The application during fruit development can also be split into two if the flowering and fruiting is protracted. It is imperative that trees be irrigated shortly after the

fertiliser has been applied to facilitate plant uptake and to obviate losses from leaching, run-off and volatilisation.

Table 7. Frequency of fertiliser application.

Frequency	Months	Proportion % of amount/year
4 (following late fruiting previous season)	January /February April/May July August/September	30 20 25 25
5 (following early fruiting previous season)	December/January March/April May/June August September/October	30 20 20 15 15

Organic fertiliser application

Organic fertilisers such as animal manure should only be used as supplements as one has to use large amounts to equate to the inorganic fertilisers as they are very low in macro-elements. Growers are encouraged to use them to improve soil structure, water holding capacity as well as soil fertility. One guideline is shown in Table 8.

Table 8. Schedule and rates for chicken manure fertiliser.

Tree age Year	Amount kg/tree/year	Freq/ year	Dynamic Lifter (g)				Common chicken manure (g)			
			N (4%)	P (3%)	K (1%)	Ca (7%)	N (5%)	P (2%)	K (1%)	Ca (3%)
3	2	1	80	90	20	140	150	40	20	90
4	4	1	160	120	40	280	200	80	40	120
5	5	2	200	150	50	350	250	100	50	150
6	6	2	240	180	60	420	300	120	60	180
7	8	2	320	240	80	560	400	160	80	240
8	10	2/3	400	300	100	700	500	200	100	300
9	10	2/3	400	300	100	700	500	200	100	300

Liming, calcium and magnesium replenishment

For rambutan, the optimum pH range is between pH 5.5 to pH 6.5 and soils with lower pH levels have to be limed to raise the pH level. The usual practice is to lime the soil to raise soil pH with dolomite, dolomite and lime, or dolomite and gypsum. Gypsum has a negligible effect on pH change but can correct for both sulphur and calcium deficiency. Lime alone is very effective in raising the pH but supplies only Ca. Dolomite which contains 15-22% Ca and 8-20% Mg, depending on the source, supplies both Ca and Mg and is also effective in raising soil pH. The actual amount of lime or dolomite to use to correct the pH depends on

the soil type, soil pH and chemical source. For example, to raise the pH from < 5 to 6 may require up to 5 tons/ha of lime or dolomite. Liming is recommended once a year for rambutan as most soils are low in calcium and this may be done in Jan/Feb or May/Jun. We reiterate again here that the

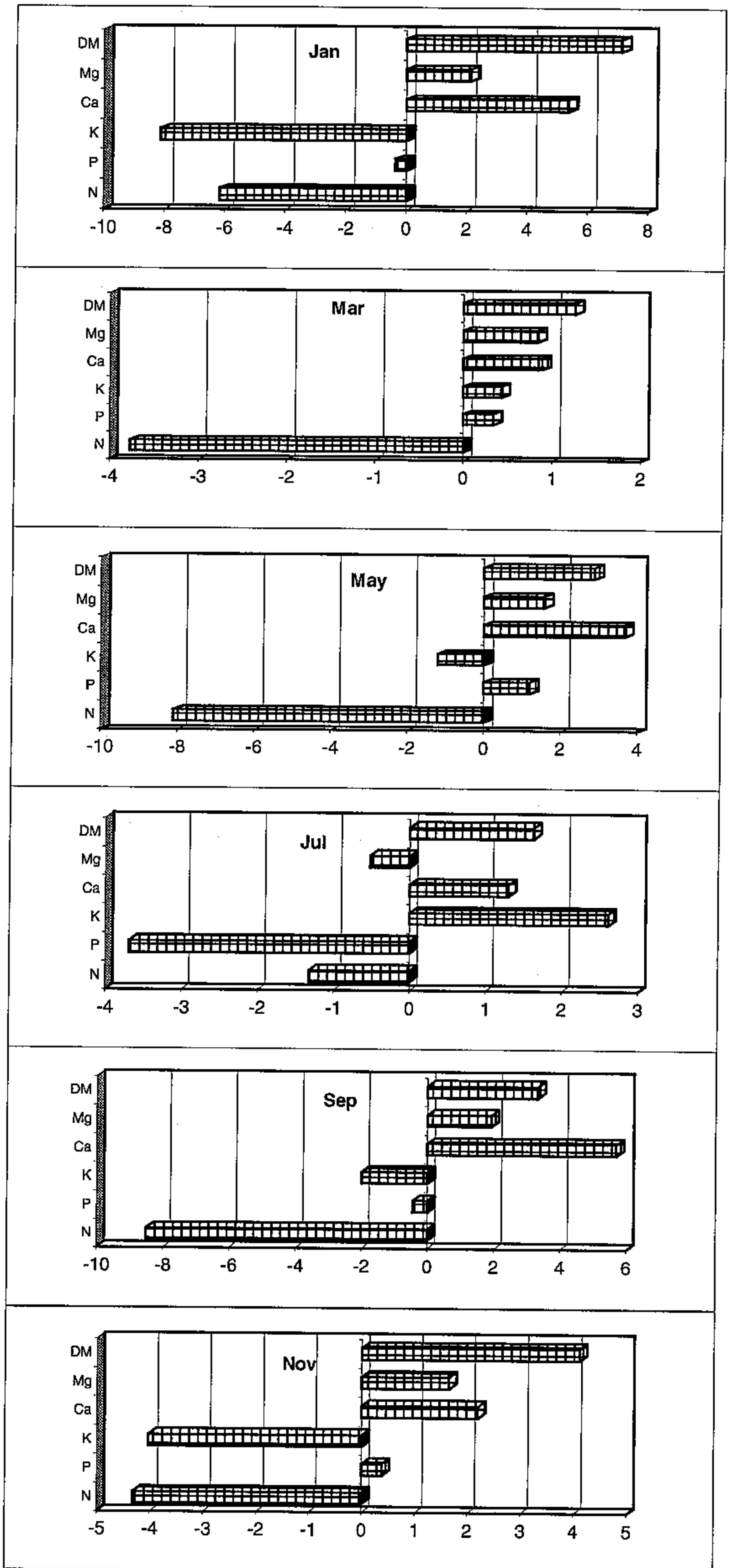

Fig. 1 M-DRIS indices of rambutan leaf macronutrients at different months

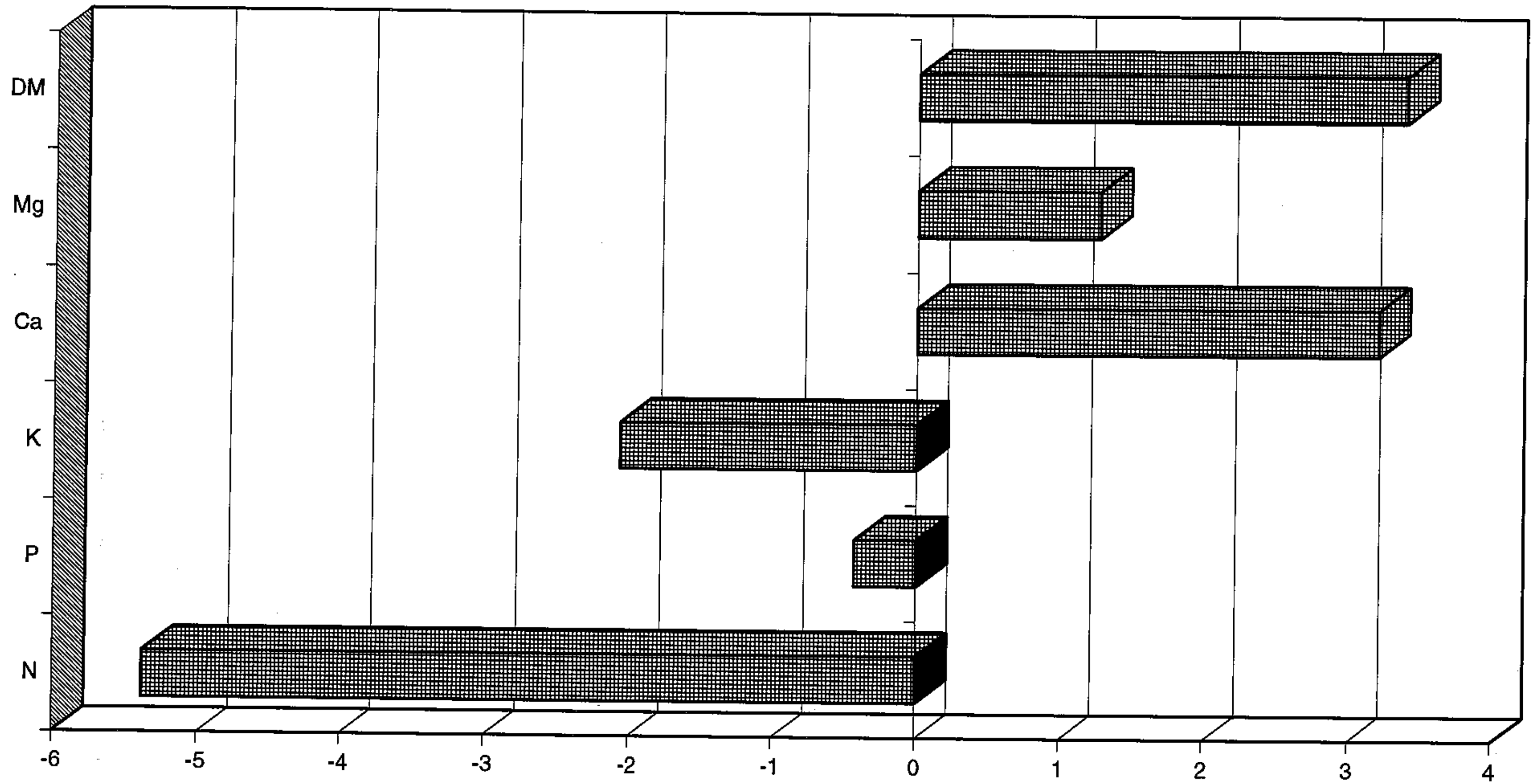

Fig.2 M-DRIS indices of rambutan leaf macronutrients 1992-1995

rambutan orchards around Darwin tend to have a low Ca:Mg ratio which ideally should be around 6. Thus for rambutan, lime or calcium sulphate is more preferable than dolomite. Calcium deficiency is common on acid soil of low pH which fixes calcium making it unavailable and also in soil with high nitrogen or phosphorus. Calcium deficiency can also be easily corrected by foliar sprays of calcium nitrate (5-15 g/L) or calcium chelate (2-3 g/L). Such calcium compounds should never be used with sulphate salts of other elements as this will result in precipitation of the insoluble calcium sulphate. When both calcium and magnesium need to be replenished, the amount of dolomite that has to be used can be obtained from the following table.

Table 9. Application rates of dolomite fertiliser.

Tree age	year	3	4	5	6	7	8	9	10
Yield	kg/tree/year	10	15	20	30	40	50	60	75
Ca removed	in g	8.91	13.37	17.82	26.73	35.64	44.55	53.46	66.83
Mg removed	in g	4.00	5.99	7.99	11.99	15.98	19.98	23.98	29.97
Dolomite	amount g/tree	300	400	500	600	700	800	900	1000
Ca 15 %	Ca (g) supplied	45	60	75	90	105	120	135	150
Mg 8%	Mg (g) supplied	24	32	40	48	56	64	72	80
Dolomite	amount (g)	300	400	500	600	700	800	900	1000
Ca 15 %	Ca (g) supplied	45	60	75	90	105	120	135	150
Mg 20%	Mg (g) supplied	60	80	100	120	140	160	180	200
Dolomite	amount (g)	250	350	450	550	650	750	850	950
Ca 22%	Ca (g) supplied	55	77	99	121	143	165	187	209
Mg 8%	Mg (g) supplied	20	28	36	44	52	60	68	76
Dolomite	amount (g)	250	350	450	500	600	700	800	900
Ca g (22%)	Ca (g) supplied	55	77	99	110	132	154	176	198
Mg g (20%)	Mg (g) supplied	50	70	90	100	120	140	160	180

Micro-nutrient fertilisation

Fruit trees require these micro-elements in very sparing quantities. Deficiencies of micro-nutrients are easily detectable by visual qualitative symptoms. Rambutan in the NT usually suffer from deficiencies of zinc, iron and boron and sometimes manganese. Deficiencies of these elements can be corrected by foliar sprays or soil application. For foliar applications, sprays are timed to coincide with the appearance of new vegetative flushes, ie. in January/February, March/April and May/June. Soil application can be administered via soil drenching or fertigation. In cases of acute deficiencies, 2-3 consecutive sprays 10-14 days apart may be necessary. A small quantity of a wetting agent or a small amount of 0.5-1 % urea (low in biuret) can be added to aid absorption by the foliage.

Zinc

Zinc deficiency is common on calcareous soils with pH > 6, acid leached soils, coarse sands, high organic soils or soils low in organic matter and heavily limed soils. On sandy acid soils liming can induce Zn deficiency. Zinc is variably mobile in plants and deficiency symptoms take the form of little leaf, rosette terminal formation, or chlorotic mottles in less severe cases. Zinc deficiency can be corrected by using zinc chelate or zinc sulphate heptahydrate at 2 g/L spray, or the latter at 7-8 g/m^2 soil application or zinc oxide soil application at 5 g/m^2.

Iron

Iron is rather abundant in many soils but often in a form unavailable to the plant. Iron deficiency is induced when there is too high soil water and low soil temperature. High pH or free calcium carbonate induces iron chlorosis despite adequate iron levels in the plant. Deficiency appears as interveinal chlorosis and in severe cases bleaching of young foliage followed by necrosis. Iron deficiency can be overcome by using iron chelate at 1 g/L spray or 2-3 g/m^2 soil applied or 3-5 g/L ferrous sulphate spray. On calcareous soils or high pH soils avoid soil application.

Manganese

Manganese deficiency is especially evident on light sandy soils. Low organic matter affects its availability, a high soil pH greater than pH 6.5 decreases its availability. High calcium or magnesium interferes with its uptake and low sulphur makes its less available to the plant. Diagnostic symptoms consist of interveinal chlorosis becoming necrotic with time and new growth is affected first as the element is rather immobile. Manganese deficiency can be ameliorated by spray applications of manganese sulphate at 2 g/L or manganese chelate at 1 g/L.

Boron

Boron aids in the movement of Ca in plants and also helps in the accumulation of sugars and starches. It is necessary for pollen germination, flower and fruit development. The element is rather immobile in plants. Deficiency occurs when the plant is expanding rapidly during flowering, fruiting or during periods of drought. Obvious symptoms include death of growing points, incomplete development of fruits, deformed fruits and reduced plant quality. B is deficient in high pH soils or heavily limed soils. Too high levels of NPK also induce B deficiency. B is greatly leached in light textured sandy soils, acid soils or soils low in organic matter. Deficiency can be corrected by using borax or Solubor®. Borax is not compatible with

other chemical sprays and is use on its own as 1-3 g/L sprays or 2-3g/m^2 soil application. Solubor® is more compatible and can be used at 0.5-2 g/L sprays but avoid mixing with zinc sulphate which results in precipitation of the insoluble salt. Solubor® is compatible with calcium nitrate or calcium chloride sprays, liquid NPK fertiliser eg. ammonium nitrate, urea, diammonium phosphate and potassium chloride. Solubor® is only compatible with manganese sulphate at low rates.

Copper

Copper deficiency characterised by curling, wilting and death of young shoots is not common on rambutan because of sprays of protective copper containing fungicides used at rates of 5-10 g/L for control of diseases in rambutan. Copper is absorbed by leaves but copper translocation in plants is poor due to the low mobility of copper.

Molybdenum

Molybdenum deficiency characterised by paling and yellowing of leaves is not common in rambutan. It can occur on soils rich in iron and aluminium, or in acid soils below pH 5. Deficiency can be corrected by liming such soil or by sprays of sodium molybdate at 1 g/L.

Sources and composition of chemical fertilisers

The sources of fertilisers supplying macro- and micro-nutrients used for ground application and fertigation are shown in Tables 11 & 12. The chemical formulae, chemical composition and practical solubility at 25°C are listed.

Fertigation

Fertilisers can be applied through the irrigation system. This process is commonly referred to as "fertigation". Soluble forms of commonly available fertilisers are selected or special proprietary soluble/liquid fertiliser mixes can be used. Fertigation has a number of advantages and disadvantages compared to adding granular fertilisers. The advantages are:

- nutrients can be applied in small amounts regularly as the tree requires them.
- this leads to increased fertiliser use efficiency and sometimes an improvement in yield.
- nutrients are applied directly to the root system within the wetted area ensuring minimum losses.
- leaching losses after rain are minimised due to split applications.
- labour and machinery costs are reduced as fertilisers do not have to be supplied individually to each tree.

- well designed injection equipment can be convenient to use and lends itself to automation.

Some of the disadvantages of fertigation are:

- up front capital cost of fertigation equipment.
- soluble grades of fertiliser are often more expensive than granular fertilisers.
- require the ability to calculate fertiliser mix based on solubility of fertiliser and nutrient requirements.
- become reliant on equipment which needs to be well maintained and may fail at times.
- need to pay attention to storing, handling and mixing of fertilisers.
- irrigation is still required to apply fertilisers during the wet season.

There are no tried and tested fertigation recipes for rambutan, however, a schedule can be calculated based on the granular fertiliser program. A regular soil and leaf nutrient monitoring program will allow modifications to be made. If fertigating then the frequency of application should be increased to 10-12 times per year. A simple application schedule could be as presented in Table 10.

Table 10. Schedule for fertigating rambutan

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Application	1	2	1	1			1#	1	1	1	1	1

apply when greater than 50% of trees are in flower

Fertiliser selection for fertigation

Nitrogen (N)

Commonly used forms of nitrogen in fertigation are: ammonium nitrate, ammonium sulphate, urea and calcium nitrate. Ammonium sulphate is very acidifying and urea is mildly acidifying. Hence, care must be taken to ensure the soil pH balance is not altered.

Phosphorous (P)

When fertigating it is essential that fertilisers which contain P are not mixed with fertilisers containing calcium (Ca) as a precipitate will form. Phosphorous will also form insoluble compounds with other chemicals, so care should be taken when injecting P. In fact it is often best to inject P by itself. Common forms of P for fertigation are: phosphoric acid (liquid available in two concentrations) and irrigation grades of diammonium phosphate (DAP) and monoammonium phosphate (MAP).

Potassium (K)

Fertilisers containing K used for fertigation include: potassium sulphate (sulphate of potash), potassium nitrate and potassium chloride (muriate of potash). Potassium chloride should not be used for fertilising rambutans, despite the fact that it is a good, soluble and cheap source of K, as rambutan is extremely sensitive to chlorides.

Calcium (Ca)

The major calcium source used in fertigation is calcium nitrate. It is an expensive fertiliser. It is recommended that Ca fertiliser be injected separately due to potential precipitation problems. The Ca requirements of rambutans are easily satisfied by liming, hence injectable sources of Ca should not be required by most growers.

Micro-nutrients

Micro-nutrients such as zinc, iron, manganese, magnesium, boron and molybdenum can be applied via fertigation. The amounts to be applied are usually small and care needs to be taken to accurately weigh the ingredients. Many commonly used fertilisers (Tables 11 & 12) which supply essential macro- and micro- nutrients are suitable for fertigation.

Fertigation equipment

For fertigation to be successful the irrigation system must be well designed. This should, of course, be so in any case because efficient irrigation management of rambutans also requires that all the trees in an irrigation block are receiving the same amount of water per irrigation. There are four main methods of injecting fertilisers: pumps (electric or hydraulic), pressure differential systems, vacuum (venturi) systems and suction systems. The method you choose will depend on how you wish to manage the system. Pump systems offer the most control and can be set up to inject fertiliser proportionally or a set quantity in a given amount of time. Examples of pump systems include hydraulically driven pumps such as Dosatron, TMB and AMIAD or electrical pumps such as the Prominent metering pump, centrifugal, piston, diaphragm, gear, and helical rotor pumps. The important part of pumping systems is that the pressure at the injection point must be higher than the irrigation system pressure.

Table 11. Chemical composition and solubility of fertilisers sources supplying macro-nutrients.

Source of fertiliser	Chemical formula	% N/P/K/Ca/Mg/S	Practical solubility (kg/100L) at 25°C
Nitrogen N			
Urea	$CO(NH_2)_2$	45	78
Ammonium nitrate	$NH_4\ NO_3$	33.5 - 34	100
Ammonium sulphate	$(NH_4)_2\ SO_4$	20	71
Aqua ammonium	$NH_3 + H_2O$	20-24	
Ammonium phosphate	$NH_4\ H_2PO_4$	10-11	23
Ammonium nitrate of lime	$NH_4\ NO_3 + CaCO_3$	20.5	
Ammonium polyphosphate dry form	$NH_4H_2PO_4 + (NH_4)_3HP_2O_7$	10	
liquid form		15	
Di ammonium phosphate	$(NH_4)_2\ HPO_4$	18	43
Potassium nitrate	KNO_3	13	
Calcium nitrate	$CaNO_3$	15.5	
Sodium nitrate	$NaNO_3$	16	
Phosphorus P			
Monosuperphosphate	$Ca(H_2PO_4)_2 + CaSO_4$	8.8	
Triple superphosphate	$Ca(H_2PO_4)_2$	19.8	
Monoammonium phosphate	$NH_4\ H_2PO_4$	21.1	23
Diammonium phosphate	$(NH_4)_2HPO_4$	20.2	43
Ammonium polyphosphate dry form	$NH_4H_2PO_4+(NH_4)_3HP_2O_7$	15	
liquid form		27.3	
Phosphoric acid - 60%		19	liquid
Phosphoric acid - 85%		26.8	liquid
Potassium K			
Muriate of potash (Potassium chloride)	KCl	49.8	30 (not for rambutan)
Potassium sulphate	K_2SO_4	41.5	10
Potassium nitrate	KNO_3	36.5	31
Calcium Ca			
Dolomite	$CaCO_3 + MgCO_3$	15-22	
Gypsum	$CaSO_4$	22	
Calcite	$CaCO_3$	40	
Lime 90% pure	$CaCO_3$	36	
Slaked Lime	$Ca(OH)_2$	54	
Monosuperphosphate	$Ca(HPO_4)_2 + CaSO_4$	20	
Triple superphosphate	$Ca(H_2PO_4)_2$	14	
Calcium nitrate	$CaNO_3$	19	60
Magnesium Mg			
Dolomite	$CaCO_3 + MgCO_3$	8-20	
Epsom salt (Magnesium sulphate)	$MgSO_4.7H_2O$	10	71
Kieserite	$MgSO_4.H_2O$	18	
Potassium magnesium sulphate	$K_2SO_4.2MgSO_4$	11	
Sulphur S			
Ammonium sulphate	$(NH_4)_2SO_4$	24	71
Potassium sulphate	K_2SO_4	18	10
Potassium magnesium sulphate	$K_2SO_4.2MgSO_4$	23	
Epsom salt	$MgSO_4.7H_2O$	14	71
Monosuperphosphate	$Ca(H_2PO_4)_2 + CaSO_4$	14	
Gypsum (Calcium sulphate)	$CaSO_4.\ 2H_2O$	17	
Elemental sulphur	S	88-100	

Table 12. Chemical composition and solubility of fertiliser sources supplying micro-nutrients.

Source of fertiliser	Chemical formula	% element*	Practical solubility (kg/100L) at 25°C**
Boron B			
Borax	$Na_2B_4O_7.10H_2O$	11	
Boric acid	H_3BO_3	17	
Sodium pentaborate	$Na_2B_{10}O_{16}.10H_2O$	18	
Sodium tetraborate			56
Fertiliser borate 46	$Na_2B_4O_7.5H_2O$	14	
Fertiliser borate 65	$Na_2B_4O_7$	20	
Solubor®	$Na_2B_{10}O_{16}.10\ H_2O$	20	22
Copper			
Copper sulphate	$CuSO_4.3Cu(OH)_2$	13-53	
Cuprous oxide	Cu_2O	89	
Cupric oxide	CuO	75	
Copper acetate	$Cu(C_2H_3O_2)_2.\ H_2O$	32	
Copper oxalate	$Cu\ C_2O_4.1/2H_2O$	40	
Copper chelate	$Na_2CuEDTA$	13	
Copper ammonium phosphate	$Cu(NH_4)PO_4.H_2O$	32	
Manganese Mn			
Manganese sulphate	$MnSO_4.3H_2O$	26-28	105
Manganese oxide	MnO	41-68	
Manganese carbonate	$MnCO_3$	31	
Manganese chloride	$MnCl_2$	17	
Manganese oxide	MnO_2	63	
Manganese chelate	MnEDTA	12	
Zinc Zn			
Zinc sulphate	$Zn\ SO_4.\ H_2O$	36	22
Zinc oxide	ZnO	78	
Zinc carbonate	$ZnCO_3$	56	
Zinc chelate	$Na_2ZnEDTA$	14	
Iron Fe			
Ferrous sulphate	$FeSO_4$	36.77	
Sodium iron edetate (Iron chelate)	NaFeEDTA	15.22	29
Molybdenum Mo			
Ammonium molybdate	$(NH_4)_6Mo_7O_{24}.2H_2O$	54	
Molybdenum trioxide	MoO_3	66	
Sodium molybdate	$Na_2MoO_4.2H_2O$	39	56
Chlorine Cl (not for rambutan)			
Ammonium chloride	NH_4Cl	66	
Calcium chloride	$CaCl_2$	65	
Magnesium chloride	$MgCl_2$	74	
Muriate of potash (potassium chloride)	KCl	47	30
Sodium chloride	NaCl	60	

* Dohanue *et al.*, 1990. ** Nakayama and Bucks, 1986

Formulation of a fertigation mix (Table 13)

Assumptions:

Tree age = 10 years

Number of trees in a irrigation block = 200

Sprinkler flow rate = 90 L/hr

Total flow rate = 18000 L/hr

Canopy ground area per tree = $38m^2$

Table 13. Fertigation injection requirements for 10 year old rambutan trees based on rates in Table 6.

Macro-element/micro-nutrient fertiliser	Annual requirement	kg/200 trees/year	kg per injection
Macro-element			
Nitrogen	550 g/tree/year	110	10
Phosphorous	275 g/tree/year	55	5
Potassium	495 g/tree/year	99	9
Micro-nutrient fertiliser			
Zinc sulphate	7 g/m^2/year, zinc sulphate	53	4.8
Iron chelate	2.5 g/m^2/year iron chelate	19	1.727
Manganese sulphate	1.0 g/m^2/year manganese sulphate	7.6	0.69
Solubor®	1.0 g/m^2/year, Solubor	7.6	0.69
Sodium molybdate	0.1 g/m^2/year, sodium molybdate	0.76	0.69

Ideally, the above fertilisers should be added in three separate lots of 200 L of water per injection period to avoid any incompatibility problems. Mix 1 can include N, P and K. Mix 2 can include Zn, Fe, Mn and Mo and Mix 3 would be B by itself. Note the following mixes are examples only. If you wish to use other fertilisers do so after consulting with DPIF Horticulture or your fertiliser supply representative.

Calculation of the above major ingredients

Mix 1

Step 1

N = 10 kg, P = 5 kg and K = 9 kg

Calculate the P requirement using MAP from information in Table 13

MAP = 12% N and 27% P

Therefore to apply 5 kg of P per injection you will require

5 x 100/27 kg = 18.5 Kg of MAP

The amount of N in the 18.5 kg of MAP has to be calculated

N = 18.5/100 x 12 = 2.2 kg

Step 2

Next calculate the K requirement using 2/3 potassium nitrate (KNO_3) and 1/3 potassium sulphate (K_2SO_4). Therefore the 6.0 kg of the K requirement will be supplied by KNO_3 and 3.0 kg by K_2SO_4.

KNO_3 = 6/39 x 100 = 15.4 kg

The amount of N in the above amount of KNO_3 is

N = 15.4/100 x 14 = 2.16 kg

K_2SO_4 =3/41 x 100 = 7.32 kg

The amount of S in the above amount of K_2SO_4 is

S = 7.32/100 x 18 = 1.32 kg

Step 3

Calculate the remaining N requirement using urea

Total N required = 10 kg, N supplied by MAP = 2.2 kg, N supplied by KNO_3 = 2.16 kg.

Remaining N required = 10 - 2.2 -2.16 = 5.64 kg.

Urea = 5.64/46 x 100 = 12.26 kg

Therefore Mix 1 will be made up of:

18.5 kg MAP, 23.1 kg KNO_3 7.32 kg K_2SO_4, 12.26 kg Urea

The least soluble of the above is K_2SO_4 (10 kg/100 L). At least 200 litres should be used to dissolve the mix. It is advisable to check the solubility of fertiliser mixes by using a jar or bucket test. Mix the proportional amounts of fertiliser in 1.0 or 5.0 litres of water and check for any solubility problems.

Mix 2

Mix 2 consists of 4.8 kg zinc sulphate, 1.73 kg iron chelate, 0.69 kg manganese sulphate and 0.069 kg sodium molybdate. The above micronutrients are all highly soluble. However, given that they are being mixed and need to be distributed evenly over the 200 trees, it would be advisable to dissolve them in the maximum amount of water (200 L).

Mix 3

Mix 3 comprises 0.69 kg Solubor® on its own. Solubor® is very soluble, however to ensure as even distribution as possible it should also be mixed with the maximum amount of water (200 L).

Fertigation injection time

Injection times depend on the injection rate of the pump, the volume of liquid to be injected, the normal run time of the irrigation system and the distance from the injection point to the orchard. Normally fertilisers are injected in the middle half of the irrigation cycle with sufficient time given to fill and flush the system. Travel times can be a calculated by adding the travel time through each pipe segment. For each pipe size the calculation is:

Time = Distance/Velocity = Distance x Inside area of pipe/Flow rate through pipe

Distance = metres

Pipe area = sq metres

Flow rate = cubic metres/second

Time = seconds

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