Fertiliser Recommendations

for horticultural crops

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Note for Bulletin Users

The appearance in this bulletin of fertiliser products associated with particular companies, or products bearing registered trade marks does not imply endorsement of these materials by the Ministry of Agriculture and Fisheries. Where they have been used it has been as examples of materials that are available commercially. It does not imply that these materials are superior to those with similar specifications which have been omitted.

Design and paste-up: Craig Meek

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C O N T E N T S

APPENDIX

ACKNOWLEDGEMENTS

PREPARATION OF THE BULLETIN

This bulletin has been written by scientific and advisory staff in the Ministry of Agriculture and Fisheries in response to the need for a comprehensive treatise on the nutrient requirements of horticultural crops in NZ. The Ministry acknowledges the assistance of scientists and advisors from other organisations in providing information and acting on an Advisory Committee. This committee was set up to advise on the format of the bulletin and technical contents, and oversee subsequent revisions.

Members of the Advisory Committee

Mr N.A. Cullen	Director, Ruakura Soil and Plant Research Station, MAF, Chairman
Dr I.S. Cornforth	Scientist, Ruakura Soil and Plant Research Station, MAF
Mr J.A. Douglas	Scientist, Ruakura Soil and Plant Research Station, MAF
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Mr G.E. Malden	Senior Technical Advisor, Auckland, Farmers' Fertiliser Co. Ltd

A number of subcommittees were subsequently set up to compile information for the various crop sections as follows:

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Dr A.R. Ferguson	Scientist, Auckland, DSIR
Mr P.B. Lyford	Horticultural Advisory Officer, Tauranga, MAF
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Mr S.J. Wheeler	Technical Advisor, Napier, East Coast Fertiliser Co. Ltd

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Information submitted by the respective committees plus that added at the latter stages by the editors, was compiled and edited by Drs C.J. Clark, G.S. Smith, I.S. Cornforth (Ruakura) and M. Prasad (Levin). The assistance of others including Messers G. Bilbrough and R. Brewer and Mrs R. Williams (MAF) in preparing this bulletin for publication are also acknowledged.

The names of major contributors appear adjacent to the sections with which they were mainly involved. Bulletin users who require clarification of specific points should contact either their local MAF ASD horticultural specialist or the specific crop chairman.

REVISION OF THE BULLETIN

While the material in the bulletin is as complete and up to date as possible, little information is available on many crops and it is planned to revise the bulletin at regular intervals as new information becomes available. The Advisory Committee will continue to exercise an oversight and make recommendations on changes needed.

Comments and amendments for consideration in future revisions should be sent to a member of the editorial committee at Ruakura.

I N T R O D U C T I O N

(G.S.Smith, I.S. Cornforth, C.J. Clark, G.E. Malden)

The past two decades have seen a remarkable increase in horticultural production in NZ. Many new crops are now grown for which basic information on fertiliser requirements is not readily available. In addition, many different types and formulations of fertiliser are appearing on the market which further add to the growers' confusion about which fertiliser should be applied.

While fertiliser costs are usually a relatively small fraction of the total production costs in horticulture, incorrect decisions as to the quantity or nutrient composition of the fertiliser applied can have a disproportionate effect on the profitability of the venture. There are many recorded examples in NZ where considerable losses of production and in some cases additional effects on post-harvest storage of the crop have resulted from nutritional disorders arising from such decisions.

The purpose of this bulletin is to bring together information on fertiliser requirements of horticultural plants commonly grown in NZ. It has been written primarily for advisers and growers with the aim of answering the question; what types and rates of fertiliser are needed to maximise production of my crop? The information is largely confined to conventional solid fertilisers, but comments are included on alternative forms such as foliar fertiliser where reliable results are available.

A uniform format has been used for each crop with information on special features, nutrient composition of leaves, fertiliser requirements, and symptoms of common nutritional disorders. Additional sections have also been included on soils for horticulture, estimating nutrient requirements, monitoring the nutrient status of the crop with soil and plant analysis, and fertiliser materials and methods of application.

The reader should be aware, however, that for some crops there are large gaps in our knowledge about their nutrient requirements. In these cases the recommendations given are very tentative. It is intended to update this bulletin periodically so that new knowledge can be incorporated.

PLANT NUTRITION

Essential elements

For an element to be considered an essential plant nutrient, three criteria must be met. These are:

1. A deficiency of the element prevents the plant from completing its life cycle.
2. The deficiency is specific for the element in question.
3. The element is directly involved in the nutrition of the plant, as for example a constituent of an essential metabolite or required for the activity of an enzyme system.

The following chemical elements are known to be essential for higher plants:

Carbon	C	Potassium	K	Iron	Fe
Hydrogen	H	Calcium	Ca	Manganese	Mn
Oxygen	O	Magnesium	Mg	Molybdenum	Mo
Nitrogen	N	Boron	B	Zinc	Zn
Phosphorus	P	Chlorine	Cl		
Sulphur	S	Copper	Cu		

Plant nutrients may be divided into macronutrients and micronutrients. Macronutrients (C, H, O, N, P, S, K, Ca, Mg) are needed in plants in greater amounts than micronutrients (B, Cl, Cu, Fe, Mn, Mo, Zn). Plants may also contain considerable concentrations of non-essential elements such as aluminium which, in some cases, may be toxic to them.

SOILS FOR HORTICULTURE

The suitability of a particular area of land to grow any crop depends primarily on the climatic conditions at the site and on the physical properties of the soil. The inherent chemical fertility of the soil is less important since nutrient deficiencies can normally be corrected with fertilisers. An exception to this general statement is the presence of calcareous horizons which can induce deficiencies of Fe and Mn and preclude the cultivation of ericaceous species. Soil salinity is another chemical property which restricts the suitability of land for cropping.

While some aspects of climate can be modified by, for example wind breaks or frost control procedures, the specific climate requirements of most commercial crops normally controls their geographical distribution.

Crop plants are usually less specific in their soil physical requirements, so that we can describe properties which make a soil suitable, or potentially suitable for crop production in general.

Soil physical properties and plant requirements

Plants depend on the soil for anchorage, water and nutrients while the roots of most plants require an external supply of oxygen. Space in which roots can grow, the removal of excess water, the retention of adequate supplies of available water and the rapid exchange of air between the root surface and the soil surface all depend on a network of interconnecting soil pores with a wide range of sizes. While this pore system must be reasonably stable, pores must not be so rigid as to prevent penetration and deformation by roots. Texturally, the most suitable soils will vary from sandy to clay loams, will have a friable consistency and a stable, granular structure. The presence of compacted or cemented horizons within the normal rooting depth of the crop to be grown will restrict the movement of air, water and roots and effectively limit the depth of soil which can be exploited by plants. Such layers are still undesirable even if well below the normal range of roots. This is because they cause perched water tables to develop in wet seasons which also decrease the effective depth of available soil.

Soil temperature, which influences microbial activity, root growth and the length of the growing season, is influenced by climate, latitude, soil colour and drainage. Light coloured or poorly drained soils will warm more slowly in spring than those with darker colours and better drainage.

Soil properties and management

Topography influences the suitability of soils for cultivation with slopes greater than 12° causing problems with wheeled vehicles. While sloping land has the advantage of shedding cold air and decreasing frost hazards, it also increases the risk of erosion. Water infiltration rates and the stability of surface structure also influence erosion. The possible frequency, intensity and duration of flooding must be assessed from climate data and the internal and surface drainage characteristics of the soil.

Recontouring land to decrease slopes must be done with great caution to avoid exposing undesirable subsoil materials or producing artificial profiles with poor physical properties.

Ease of cultivation is influenced by soil compaction, the stability of aggregation, stoniness, wetness and the bearing capacity of the soil.

The need for drainage and the suitability for drainage can be assessed from soil properties already described. Similarly the need for irrigation and the method, frequency and intensity of irrigation are influenced by soil porosity through its control of water infiltration, drainage and retention.

Assessment of soils in the field

When assessing the suitability of soils for horticultural use, the principal physical properties which should be considered are slope, rooting depth, porosity, aeration, texture and the presence of compacted or cemented horizons. Aeration can be assessed by soil colours: warm brown colours imply good aeration, cold greys imply poor aeration and rusty mottles indicate alternate periods of anaerobic and aerobic conditions.

Comprehensive systems for assessing, quantifying and classifying these properties have been devised by the staff of the Soil Resources Section of the NZ Soil Bureau. Details of these systems are beyond the scope of this bulletin and should be obtained from the Soil Bureau.

Distribution of soils for horticulture

Leamy (1974) discussed the classification of NZ soils for horticulture and defined those with high actual or potential value for food production. The distinction between actual and potential value is based on the amount of amelioration required. Bollard (1981) lists the areas of soils in these categories in the main horticultural areas of the country. While the total area of such soils comprises 10% of the land area of NZ, the areas actually used for fruit or vegetable production (in 1980) varied from 0.2 percent of the possible area in Southland to 30% in Marlborough and averaged 3.4 percent for the whole country. As Bollard (1981) points out, while it is probable that in many areas the best and most easily developed land is already being used for horticulture, it is also true that there are still available large areas of land suitable for development.

ESTIMATING NUTRIENT REQUIREMENTS

The total requirement of each nutrient element for any crop depends on the yield and the average concentration of that element in the tissues of the plant needed to secure that yield. In many instances detailed information from fertiliser trials on the quantity of fertiliser needed to maintain maximum production is currently lacking, particularly for the diverse soil types and climates which exist in this country. In the absence of such information an alternative approach has been adopted in this bulletin which involves estimating the quantity of nutrients removed in the marketable yield. Nutrients lost in this manner represent the minimum amounts needed to be replaced from soil reserves or fertiliser additions each year if yields are to be maintained. Allowances also need to be made for nutrients removed from the root zone by leaching and for the efficiency with which crops can absorb nutrients applied in fertilisers. The extent to which nutrients are transported down the soil profile varies considerably between soils. Freely drained soils are very prone to nutrient removal by leaching. Of the major plant nutrients, phosphates are leached at the slowest rates while nitrates are readily leached. Fertiliser nutrients are also rendered at least temporarily unavailable to plants if they are strongly adsorbed by soil particles or are incorporated into organic materials in soils.

FERTILISER MATERIALS

Having determined the amount of each nutrient element required to maintain maximum production, recommendations must be converted into rates of commercially available fertiliser materials.

All fertilisers are registered and sold in NZ under the element rating scheme which is expressed as the percentage of NPK in the material. In some countries however, nutrient content is expressed in terms of the oxide concentrations; P_2O_5 for P and K_2O for K. Nitrogen is expressed internationally as elemental N. These differences can lead to confusion as the P_2O_5 content is more than twice the P content. Conversion factors are as follows:

$$K_2O \times 0.83 = K$$
$$P_2O_5 \times 0.44 = P$$

Fertiliser types

The choice of fertiliser to be used depends on:

1. Nutrient content: Tables 4-10 list fertiliser materials and show their nutrient contents. In addition to these materials there is a range of proprietory mixtures available which contain various combinations of the plant nutrients.

2. Nutrient concentrations: These are also listed in Tables 4-10. These figures are needed to calculate fertiliser rates from requirements given in elemental terms (see below), and to calculate the relative value of fertiliser materials in nutrient terms.

3. Cost per kg of nutrient: This is calculated by dividing the cost per tonne of fertiliser by its nutrient concentration multiplied by 10.

For example:
Urea 46% N, $452/tonne

$$\text{Cost per Kg N} = \frac{452}{46 \times 10} = \$0.98$$

Calcium Ammonium Nitrate (CAN), 28% N, $543/tonne

$$\text{Cost per kg N} = \frac{543}{28 \times 10} = \$1.94$$

In this example, urea is about half the cost per unit of N than CAN.

4. Nutrient availability: This refers to both the proportion of nutrients applied in fertilisers which is available to plants, and the rate at which they become available. Water soluble nutrients (such as the K in all K fertilisers) are immediately available for either uptake by plant roots, to react with soil materials, or to be washed out of the root zone. Some water insoluble nutrients such as N in organic fertiliser must be released by microbial action before they are available to plants. Other water insoluble nutrients dissolve so slowly that they are of little value to plants, while in others the rate of release of nutrients can satisfy the plants demand. Variable nutrient availability is most important when selecting sulphur and phosphate fertilisers.

   Sulphate-S (superphosphate, ammonium sulphate) should be used when an immediately available supply is required and when leaching losses are not likely to be serious. Elemental S should be used when a more sustained supply is needed, especially on free draining soils in high rainfall areas. Sulphur fortified superphosphate contains both forms.

   Phosphorus applied in superphosphate is rapidly available to plants but can also react with soil constituents which decrease its value. The slower release of plant available P from reactive rock phosphates such as those from North Carolina or Sechura, in Peru, may provide less initial benefit to plants but will have an effect for a longer period. Research on the value of rock phosphates for direct application is continuing, but they may have considerable value on acid soils (pH 5.5) and in remote areas where transport costs make their greater P concentration attractive.

   A more attractive alternative are the new partially acidulated phosphate rocks (PAPR) which are becoming available commercially and show promise for both agricultural and horticultural crops. These fertilisers have both quick release phosphate for immediate supply to plants, and slow release unreacted rock phosphate for long term supply.

   Phosphoric acid acidulated PAPRs are high analysis fertilisers containing plant available P in excess of 16%. Their S content is negligible however. These types of products are available under different trade names such as PAPR and PARPR. Sulphuric acid acidulated PAPRs contain smaller amounts of plant available P (≈ 10%) but their sulphate-S content is greater than 6%. When these latter fertilisers become commercially available, PAPRs will offer the flexibility of adjusting the P/S ratio of fertiliser to match particular plant requirements.

   All forms of N fertiliser generally give similar responses per unit of material. Urea and nitrate-N in calcium ammonium nitrate are subjected to greater leaching losses than ammonium sulphate.

   Magnesium fertiliser sources include highly soluble materials such as Kieserite and Epsom salts which are best used for correcting existing deficiencies, and slow release materials such as calcined magnesite and dolomite which may be more suitable for building up or maintaining soil reserves.

5. Physical form: Water insoluble materials like elemental S and some rock phosphates must be finely ground if they are to release their nutrients fast enough for plant requirements. However, fine grinding increases handling problems and in the case of S, the risk of explosions. Compromises in which finely ground rock phosphates are formed into granules which decompose in soil, or in which molten elemental S is used to fortify superphosphate are desirable and it cannot be overemphasised that coarse particles of S or phosphate rocks are of little value as fertilisers, especially in dry, cool conditions; slightly coarser S can be used in warm humid climates.

6. Organic fertilisers: Poultry, sheep, cow and stable manure all have a valued contribution and as they have varying degrees of nutrient content it is not easy to give any precise figures. Typical NPK rating of these materials are in Table 1.

Table 1: Approximate composition of organic materials

	N%	P%	K%	Organic Matter %
Cow manure	0.7	0.2	0.5	30
Horse manure	0.7	0.15	0.4	60
Pig manure	1.0	0.3	0.7	30
Sheep manure	2.0	0.5	2.3	60
Poultry manure	1.6	0.6	1.6	50
Seaweed (kelp)	0.2	0.05	0.5	80
Grain straw	0.6	0.10	1.05	80

7. Clear liquid fertilisers: There are a variety of brands on the market which are sold for foliar application and in some cases for inclusion in irrigation systems. They are expensive for using as base nutrient fertilisers but can be valuable as carriers for micronutrients and as foliar feeds to correct nutrient deficiencies. Some materials suitable for clear liquid fertilisers are in Table 2.

Table 2: Materials suitable for preparing clear liquid fertilisers

	N%	P%	K%
Potassium phosphate	0	21	25
Diammonium phosphate (technical grade)	21	23	0
Phosphoric acid 52% P_2O_5	0	22	0
85% P_2O_5	0	37	0
Ammonium nitrate crystals	35	0	0
Calcium ammonium nitrate crystals	28	0	0
Potassium nitrate	14	0	39
Urea	46	0	0

8. Suspension fertilisers: Suspensions compete on a nutrient price basis with solid NPKS fertilisers. They are very useful for accurate row crop application and placement especially under adverse weather conditions when high analysis NPK fertiliser becomes wet and sticky. They are formulated on an ammonium phosphate base with muriate of potash used for the K source. Extra N is added as urea.
9. Slow release fertilisers: These are used for high value crops. A wide range of slow release fertiliser materials is available, varying in release rates from a few months to more than a year. Use of these materials is primarily for one or more of the following reasons:

   (i) Availability of nutrient during the entire growing season from just one application.
   (ii) Reduced capital and labour outlay.
   (iii) Reduced nutrient loss from leaching.
   (iv) Reduced leaf burn from heavy rates of fertiliser applications.
   (v) Reduced seed and seedling damage from high local concentrations of salts.
   (vi) Reduction of nitrogen losses through ammonia volatilization and denitrification.

   The availability of fertiliser material is controlled either by using compounds with limited water solubility or by coating soluble materials with polymers or S. The release rate of nutrients is generally affected by temperature, moisture content, and pH of the substrate. For example the release of N from Nutricote (270 day) was 16% at 20 °C but 45% at 32 °C. Detailed release rates for various commercial compounds are given in Table 3.

Application Rates

Having chosen the type of fertiliser to use, calculate the rate to apply from the estimate of the elemental requirement and the concentration of the available nutrient in the fertiliser:

$$\text{Rate of fertiliser} = \frac{100 \times \text{nutrient required by plants (kg/ha)}}{\text{Nutrient concentration in fertiliser}}$$

For N, K, S and Mg fertilisers use the total concentration of the nutrient in this calculation. For example, a kiwifruit crop requiring 100 kg N/ha; how much urea (46% N) should be applied?

$$\frac{100 \times 100}{46} = 217 \text{ kg/ha of urea}$$

The situation is less simple for phosphate fertilisers. For superphosphate and rock phosphate based materials (Tables 5 and 6) fertiliser requirements should be calculated by multiplying the kg/ha of P required by a factor based on the concentration of P in the material that is plant available rather than the total P content. Estimates of the concentration of plant available P in phosphate materials are given in Tables 5 and 6.

$$\text{Rate of fertiliser} = \frac{100 \times \text{nutrient required by plants (kg/ha)}}{\text{Plant available P\%}}$$

For example, a citrus crop requiring 68 kg P/ha; how much 15% Potassic Magphos (Plant available P% = 7.7) should be applied?

Table 3: Release rates of nutrients from commercial slow release fertilisers at 20°C

Fertiliser	Release Time (months)	Elemental Content (%)	% Released (cumulative total) Time (weeks) 2	4	6	12	16	20	24
Nitrogen									
Osmocote®	8-9	18	6	17	28	62	63	–	75
Osmocote®	3-4	14	28	52	63	86	90	–	90
Osmocote®		26	2	9	17	40	52	59	63
Nutricote®	9	13	6	12	16	42	56	–	73
Gold-N®		34	8	12	17	49	65	74	77
Plantacote®	4	16	32	40	45	66	70	72	–
Plantacote®	8	16	10	15	21	45	51	55	–
IB-Compound		16	24	39	47	90	92	–	92
IB-Hardened		10	9	22	33	86	90	–	91
Phosphorus									
Osmocote®	8-9	4.8	5	16	26	39	44	–	50
Osmocote®	3-4	6.1	15	31	42	54	58	–	61
Nutricote®	9	5.7	1	2	2	3	3	–	4
Plantacote®	4	4.8	18	30	37	46	49	50	–
Plantacote®	8	4.4	17	27	34	46	50	53	–
IB-Compound		4	44	69	78	82	82	–	83
IB-Hardened		4	13	25	33	42	44	–	48
Potassium									
Osmocote®	8-9	8.3	2	5	10	30	37	–	44
Osmocote®	3-4	11.6	14	27	36	59	65	–	69
Nutricote®	9	9.1	1	2	4	14	20	–	28
Plantacote®	4	11.6	20	27	33	54	60	63	–
Plantacote®	8	10.0	15	20	25	39	44	46	–
IB-Compound		11.0	39	54	60	88	91	–	93
IB-Hardened		8.0	24	48	60	85	87	–	88

Table 4: Nitrogen fertilisers

	N%	P%	K%	S%	Equivalent Acidity
Ammoniated superphosphate	6	6	–	15	4–7
Ammonium sulphate	21	–	–	24	110
Ammonium nitrate (prills)	33	–	–	–	60
Ammonium nitrate (cryst.)	35	–	–	–	60
Ammonium phosphate sulphate	16	9	–	15	88
Blood and bone	5–8*	5–8	–	–	–
Bone dust	3–5*	9–11	–	–	–20
Calcium ammonium nitrate	26–28	–	–	–	–
Diammonium phosphate (gran.)	18	20	–	2–3	74
Diammonium phosphate (cryst.)	21	23	–	–	74
Dried blood	13–15*	–	–	–	23
Isobutylidene di-urea (IBDU)	32*	–	–	–	–
Liquid ammonia	82	–	–	–	148
Liquid nitrogen (urea solution)	20	–	–	–	40
Monoammonium phosphate (gran.)	11	21	–	2–3	55
Monoammonium phosphate (cryst.)	12	27	–	–	55
Nitram	34	–	–	–	60
Potassium nitrate	14	–	39	–	–23
Sodium nitrate	16	–	–	–	–29
Sulphur coated urea	32	–	–	27	–
Urea	46	–	–	–	79
Ureaform	38**	–	–	–	60

* Insoluble in water
** Partially soluble in water

$$\frac{100 \times 68}{7.7} = 883 \text{ kg/ha 15\% Potassic Magphos}$$

Alternatively, a blueberry crop requiring 10 kg P/ha; how much North Carolina reactive phosphate rock (Plant available P% = 13-0.5) should be applied to a soil with pH 4.8?

$$\frac{100 \times 10}{12.5} = 80 \text{ kg/ha North Carolina phosphate rock}$$

Equivalent acidity is the number of parts by weight of calcium carbonate required to neutralise the acidity caused by using 100 parts of the fertiliser. Negative values indicate the liming effect of the fertiliser.

Notes on phosphate fertilisers in Tables 5 and 6

† Citric solubility: The citric soluble P in superphosphate-based materials (other than those containing reactive rock phosphate) is the best estimate of agronomic effectiveness currently available. However it may be changed in future if research develops better indicators of phosphate value.

* The value of P in rock phosphates depends on the reactivity and the fineness of the ground phosphate rock and on the pH, calcium status and phosphate retention of the soil. The latter two effects cannot yet be quantified. Plant available P in phosphate rock can be estimated by subtracting 0.5 from the total P concentration for soils with pH < 5.5, or 2.0 from total P if soil pH is 5.5-6.0. This applies to all soils except Yellow-brown pumice soils. In this instance 2.0 should be subtracted from total P, irrespective of pH. The effectiveness of P in reactive rocks applied to soils with pH > 6.0 is not known.

These figures are based on limited field trial data and may be modified as more information becomes available. The necessary fineness of grinding will be specified in the registration regulations for each material.

Only rock phosphates classified as reactive are suitable for maintaining vigorous plant production. Reactive rock phosphates include Sechura, N. Carolina and Gafsa. Florida, Nauru and Christmas Island rocks are unreactive and are not suitable for direct application.

Table 5: Phosphate fertilisers

	Total P %	Plant Available P%	Water Soluble P%	Total S %
Aerial superphosphate	8–9	5–7†	4–5	9–11
Ammonium phosphate sulphate	9	9†	–	15
Blood and bone	5–8	4–7	Neg	Neg
Bone dust	9–11	7–10	Neg	Neg
Diammonium phosphate (granular)	19–21	18–20†	18–20	2–3
Fortefied super**	13	13	7.9	11
Longlife super**	11	9.5	5.2	8
Magphos (3% Mg)**	10	9.0	4.0	8
Monoammonium phosphate (granular)	20–21	19–20†	19–20	2–3
PAPR (30% acid)**	17	17	7.9	11
Reactive phosphate rock:				
Gafsa	13	*	Nil	Neg
North Carolina	13	*	Nil	Neg
Sechura (Peru)	13–14	*	Nil	2
Non-reactive phosphate rocks:				
Israel (Arad)	14	*	Nil	–
Florida	14	*	Nil	Neg
Jordan	15	*	Nil	–
Nauru	16	*	Nil	Neg
Christmas Island A	16	*	Nil	Neg
Potassium ortho-phosphate	23	23†	23	Nil
Lime reverted superphosphate	5–8	3–4†	1–2	5–9
Sulphur superphosphate 90 kg/tonne	8–9	6–7†	5–6	19
Sulphur superphosphate 10% S	8–9	6–7†	5–6	20
Sulphur superphosphate 180 kg/tonne	7–8	5–6†	4–5	27
Superphosphate	9–10	7–8†	6–7	10–12
Superphosphate/lime 1/1	5	3.3†	1	5
Superphosphate/lime 1/2	3	2.2†	1	4
Triple superphosphate	19–21	16–19†	16–19	1–3

** New fertilisers which contain a proportion of their total P content as reactive rock.
†* See notes
Neg — Negligible

Table 7: Potassium fertilisers

	N%	P%	K%	S%
Potassium chloride (Muriate of potash)	–	–	48–52	–
Potassium nitrate				
(Reagent grade)	14	–	39	–
(Fertiliser grade)	13	–	37	–
Potassium sulphate (Fertiliser grade)	–	–	40	17

Table 8: Sulphur fertilisers

	N%	P%	K%	S%
Ammonium sulphate	21	–	–	24
Ammonium sulphate nitrate	26	–	–	14
Di-calcic phosphate plus S	–	4	–	23
Gypsum	–	–	–	18–20
Magnesium sulphate	–	–	–	13
Potassium sulphate	–	–	40	17
Sulphur	–	–	–	100
Sulphur coated urea	32	–	–	27
Sulphur dolophos	–	6	–	17
Sulphur phosrock 5%	–	13	–	5
Sulphur phosrock 20%	–	11	–	20
Sulphur supermag	–	5	–	16
Sulphur superphosphate 10%	–	9	–	20
Sulphur superphosphate 20%	–	8	–	29
Sulphur super extra	–	7	–	27
Superphosphate	–	9–10	–	12
Super/lime 50/50	–	5	–	5
Sulphur/bentonite granules (10%)	–	–	–	90

NB: All fertiliser mixtures containing superphosphates, potassium sulphate or ammonium sulphate also contain sulphur.

Table 9: Magnesium fertilisers

	Mg%
Epsom salts	10
Dolomite	11
Kieserite	15
Serpentine rock*	18–25 (av. 20)
Calcined magnesite (Chinese)	50
Calcined magnesite (Australian Causmag)	55
Magnesium oxide (pure)	60

* Leesite/Dunite are very similar. Serpentine rock must be very finely ground to be effective.

Table 10: Trace element materials†

Element	Material	Elemental Content %
Boron	Borax	11
	Fertiliser borate – 46	14
	Boric acid	18
	Fertiliser borate – 65	20
	Solubor®	21
Copper	Copper sulphate	25
Iron	Sequestrene® 138 Fe	6
	Sequestrene® 330 Fe	10
	Ferrous sulphate	19
Manganese	Sequestrene® manganese	12
	Manganese sulphate	24
Molybdenum	Sodium molybdate	39
Zinc	Sequestrene® zinc	14
	Zinc sulphate	23

† Note, there is a wide range of proprietory brands of fertiliser containing trace elements.

Table 6: Potassium superphosphates

	Total P%	Plant Available† P%	K%	S%	Mg%
15% Potash					
Superphosphate	7–8	5.1–6.8	7	9	–
Flowmaster superphosphate	7–8	6.0–6.8	7–8	9	–
Reverted superphosphate	6	4	7–8	7	–
Superphosphate/lime 1/1	4	2.8	8	5	–
Superphosphate/lime 1/2	3	1.9	8	6	–
5% S superphosphate	7	5.4	7	14	–
Magphos	9	7.7	8	7	2
20% Potash					
Superphosphate	7	5.8	10	8	–
30% Potash					
Superphosphate	6–7	5.2–5.6	14–15	8	–
Flowmaster superphosphate	6	4.1–4.2	14	7	–
Superphosphate/dolomite 3/1	5	4.2	15	6	–
Phosrock	10	3.6	14	–	–
5% S serpentine superphosphate	5	2.9	14	10	–
S superphosphate	5	3.6	14	5	–
Magphos	7	6.3	15	5	2
50% Potash					
Superphosphate	5	4.0	25	6	–
Flowmaster superphosphate	4	2.9–3.0	24	5	–
S flowmaster superphosphate	4	2.7	22	4	–
Phosrock	7	2.5	24	–	–
Magphos	5	4.5	25	4	2

† Citric solubility, except phosrock and magphos

CALIBRATING APPLICATION EQUIPMENT

The evenness of fertiliser application is most important, especially to crops, to ensure a maximum yield.

The flow rate of fertiliser from spreaders is usually controlled by a ground driven wheel so that the faster you go the greater the flow, and a constant spreading rate per hectare is obtained. However, to measure rates accurately, metre square boxes or trays with baffles to stop the fertiliser bouncing out can be laid on the ground and the machine driven past them. The baffles can be made from any 'honeycomb' like material. Some hollow plywood household doors have a spacing material inside them which is ideal for this purpose.

Where row cropping is undertaken the fertiliser applied in the row is easily measured when the planter is in the paddock. For 75 cm (30 inch) rows the machine will have to move 13 m to equal 1/1000 of a hectare. By removing the tube which delivers the fertiliser from the box to the disc coulter and tying a plastic bag on the end, then driving a measured 13 m the weight of the fertiliser in the bag represents the rate per hectare when multiplied by 1000.

When it is necessary to determine application rates for small areas, rates given in kg/ha can be converted to g/m² by dividing by 10. Similarly, tractor speeds in km/hr can be converted to m/min by multiplying by 16.67.

MONITORING FERTILITY

While generalised maintenance fertiliser recommendations can be based on the quantities of nutrient lost in the marketable yield, they may not be sufficiently accurate to prevent nutrient disorders arising in every situation. Furthermore, for young plants additional nutrients will be required for development of the plant's framework. Therefore, it is essential to monitor closely the nutrient status of the crop with soil tests and plant analysis.

Soil testing

To be effective soil tests need to be carefully calibrated for the soils and crops of a particular region. The results of soil analysis should also be regarded more in terms of a qualitative guide to soil fertility rather than as a quantitative measure. This is because it is very difficult to find chemical extractants which will simulate the action of plant roots, especially since plant species differ widely in their ability to absorb nutrients from the soil. In addition, in many cases samples for analysis are taken from a restricted depth, usually the top 15 cm, which may not reflect the availability of nutrients from the entire root zone, particularly for deep rooted perennial plants. However, in spite of these limitations soil tests can provide valuable information about plant-available nutrients and chemical conditions in the soil, especially before a crop is planted.

A soil sample for analysis consists of 15-20 cores taken at random. Prior to establishment of orchards containing deep rooting perennial crops samples should be taken at 3 depths; 0-20, 20-40 and 40-60 cm, rather than the standard 0-15 cm used for shallow rooting pastoral species or vegetable crops. Under these conditions the tests are particularly useful for establishing whether or not gross nutrient abnormalities exist and whether there are unusual pH conditions at depth which will affect the uptake of trace elements such as Mn. Ideally, 3 x 20 cm depth sampling should be continued on an annual basis. Detailed instructions for soil sampling are given in some crop sections.

There is little definitive information available on the optimum soil test values for most horticultural crops grown in NZ. In the absence of well defined target values for each nutrient

it would seem that the presence of healthy high yielding plants should be the ultimate arbiter as to whether or not soil conditions are optimal for growth. Annual soil testing should be conducted, therefore, with the aim of monitoring and correcting trends in nutrient values rather than in the pursuit of attaining particular soil test values. One exception to this advice is for field grown vegetable crops. Work at Levin Horticultural Research Station has allowed the definition of target values for soil P and K; these are given in the sections of the bulletin covering these crops. For other crops, particularly perennials, observed trends in soil fertility represent the balance between nutrients removed for growth and production plus losses by leaching or fixation, and nutrients added in fertiliser, irrigation water, and in rainfall. Although little work has been done to define the best time during the growing season for taking soil samples for analysis, recent experiments on a number of horticultural plants at the Pukekohe Research Station suggest that samples should be taken during the early phases of growth. However, in the absence of generalised information it is recommended for purposes of comparison that samples should be taken at the same time each year.
The soil testing methods used by the Ministry of Agriculture's laboratories at Ruakura and Invermay are described in MAF Aglink AST 8. Soil test values used in this bulletin refer only to MAF soil tests. While some commercial laboratories use MAF soil test methods, others do not, and it is important to determine which methods have been used. Factors for converting MAF test units to other units are given in Appendix Table 3.

Plant analysis

Plant analysis has distinct advantages over soil analysis as a diagnostic aid for horticultural plants. Not only must the elements present in the plant originally have been available in the soil, they also reflect the availability from the entire root zone. An additional advantage of plant analysis is that all nutrient elements essential for plant growth can be determined by this technique.

Plant analysis should be used in two important ways. First, as a diagnostic aid for identifying possible causes of poor plant growth and to confirm visible leaf symptoms of suspected nutritional disorders. Sampling leaves for this purpose is independent of time during the growing season. Leaves showing distinctive symptoms should be collected as soon as they appear on the affected plants. At the same time a second sample of leaves should also be collected from an identical position on healthy non-affected plants nearby. By taking an affected and unaffected sample the results can be compared directly and possible disorders identified without having to rely upon standard values. Early identification of a deficiency also allows remedial action to be taken in the current season rather than the following season.

Secondly, plant analysis is valuable as a monitoring aid. An essential part of any fertiliser programme is to monitor the nutrient status of the crop on an annual basis. By repeatedly sampling plants at the same time each year possible trends in nutrient status, or the early onset of deficiencies or toxicities can be identified, allowing the fertiliser programme to be adjusted before substantial losses in yield occur. The sampling procedure for this purpose differs from that used for diagnostic purposes. To be meaningful, leaf samples should be taken at the same physiological stage of growth each year. This is because of the large seasonal variation in the concentration of macronutrients and micronutrients which generally occur in the leaves of most plants. It is also important that the same area is monitored each year.

After collection, leaf samples should be sent as quickly as possible to a laboratory that specialises in plant analysis. The samples should be sent in strong paper bags in preference to sealed plastic bags where they are more likely to decay.

Interpretation of the results of plant analysis is usually based on the concept of critical levels. This assumes that when the nutrient concentration in the plant tissues is very low, the yield is also low. As nutrient availability increases, both yield and nutrient concentration in the tissues increases until a point is reached where further improvement of nutrient supply no longer stimulates yield. However, the concentration of nutrient in the tissues continues to increase. At extremely high rates of nutrient supply toxic concentrations may occur in the tissues and yield will be reduced. In much of the literature, the critical concentration in the leaf for deficiency of an element is defined as the concentration range (associated with 90–100 percent of maximum yield) below which the application of that element will generally result in a yield increase and above which no such increase is to be expected. Similarly, the critical concentration in the leaf for toxicity is the concentration above which a yield reduction is to be expected. There are very few crops however for which these concentrations have been determined. Consequently, the tabulated standards for each of the crops presented are for leaf concentrations associated with deficient, optimum, and excess levels. These terms are defined as follows:

Deficient:	Concentration is too low for active growth; deficiency symptoms are likely to be present.
Optimum:	Concentrations should be adequate for near maximum growth; no visual symptoms.
Excess:	Concentrations too high for maximum growth; toxicity symptoms may or may not be present.

Used correctly, plant analysis provides the grower with valuable information about the nutrient status of his crop and the fertiliser programme being used.

Where there is particular concern about the N status of plants, or the need to increase the efficiency of N fertiliser usage, growers can use sap nitrate testing as an alternative to plant analysis. This is a rapid, sensitive technique which uses commercially available test strips to measure the nitrate concentration in expressed sap. The sampling technique and interpretation of the results is still at an experimental stage with most work having been done with vegetable crops (see the Vegetables Section and Appendix for further details). However, with further refinements it is likely to have potential for use with perennial as well as annual crops.

Visual Symptoms

Visual leaf symptoms can play an important part in diagnosing nutrient disorders. However, clearly recognisable symptoms associated with a specific disorder usually appear only after metabolic processes in the plant have been seriously disrupted and losses of yield have already been sustained. Hence the presence of visible symptoms usually indicates that a serious problem exists.

Because of differences in mobility of elements within the plant, symptoms of nutritional disorders tend to occur in particular positions on the plant. Under conditions of deficiency, elements such as N, P, K and Mg are generally withdrawn from the older leaves and transported to younger actively growing parts of the plant. Since the redistribution of these elements is by way of the phloem, such elements are classified as phloem-mobile elements. Thus, the most obvious symptoms of deficiency of phloem-mobile elements are on the older leaves. Elements such as Ca, B, Fe and Cu, which are not redistributed to any great extent in the plant under deficient conditions, are described as phloem-immobile elements. Plants must have a continuous external supply of the phloem-immobile elements to maintain healthy growth. Any interruption of the supply will cause deficiency symptoms to appear on young actively growing parts of the plant including the root tips. The remaining essential elements are of intermediate phloem mobility, but usually show symptoms of deficiency mainly on the younger growth.

Symptoms of nutrient toxicity, on the other hand, usually appear first and most prominently on the older leaves. This is because the nutrients absorbed by the plant are distributed in a pattern which closely follows that of water loss due to transpiration. The fully expanded leaves tend to receive a greater share of the water and nutrients entering the shoots than do fruit or immature leaves, because they present a large evaporating surface relative to their volume. Hence, the highest concentrations of the element in excess will be found in the older leaves since it is in these leaves that accumulation has been going for the longest period of time. In addition to having a direct effect on the plant, an excess of one element may reduce the uptake of a second element or interfere with its utilisation in the plant. Under these conditions the main symptom is likely to be that of a deficiency of the second element. The symptoms, therefore, may or may not be on the older leaves.

Because leaf symptoms can also be produced or modified by non-nutritional factors such as water-stress, temperature, light, herbicides, pests and diseases, it is important that a visual diagnosis is confirmed with plant analysis. Although there may be some differences in symptoms shown by different plant species and even varieties of the same species for a particular disorder, the basic symptoms are similar for most plants. Briefly, deficiency symptoms of macronutrients and micronutrients can be summarised as follows:

GENERALISED KEY TO NUTRIENT DEFICIENCY SYMPTOMS

Older leaves affected first

Plants much smaller than normal, leaves light green, lower leaves yellow, leaf senescence accelerated.

Nitrogen Deficient

Decreased plant size, plants dark green, often red or purple colours appearing, lower leaves yellow.

Phosphorus Deficiency

Pale brown to black leaf scorch, preceded by irregular marginal or interveinal chlorosis; leaves cupped.

Potassium Deficiency

Plants show bright yellow-green interveinal chlorotic mottling before leaf margins curl and wither. Symptoms are more intense when nitrate-N is applied. For brassicas development of the 'whiptail' syndrome and 'yellow spot' of citrus. Symptoms appear first on older leaves and progress to the youngest until plant dies.

Interveinal chlorosis, persistent green margin of leaf, yellow patches and brown necrotic areas. Appearance of brilliant orange, red or purple tints.

Magnesium Deficiency

Molybdenum Deficiency

Younger leaves affected first

Calcium Deficiency

Terminal buds die, distortion and necrosis of young leaves, die back at tips and margins. Root tips gelatinous and swollen.

Sulphur Deficiency

Decreased leaf size, pale green-yellow leaves, shortened internodes. Leaf veins become chlorotic.

Boron Deficiency

Young leaves light green-yellow at base, die back of terminal bud, leaves misshapen, thick, brittle and small. Cracks and splits occur in petioles and stems. Root tips enlarged.

Young leaves permanently wilted, without chlorosis. Leaves rolled or curled. Emerging leaves often trapped in subtending leaves. Pollen cells often sterile.

Copper

Uniform chlorosis of younger leaves, veins remain darker green.

Iron Deficiency

Chlorosis often interveinal and produces a bold pattern of dark green major veins. Unlike iron, necrotic spotting or lesions appear on affected leaves. These may be brown to black.

Manganese

Leaf malformation, irregular mottling with yellow-ivory interveinal areas and extreme rosetting of terminal and lateral shoots in woody species. In some cases necrotic spots appear on affected leaves.

Zinc

FURTHER READING

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(R.F. Barber, C.J. Clark, A.R. Ferguson, P.R. Sale, G.S. Smith)

AVOCADOS

In general, mature cropping avocado trees (*Persea americana*) have a relatively low demand for nutrients. However, differences have been identified among varieties in their demands for nutrients, particularly N. Those that require lower inputs include Fuerte and Zutano, while Hass, Bacon, Nabal and McArthur require higher inputs to maintain high production. The varieties with higher fertility requirements are particularly prone to biennial bearing. This problem is thought to be related to fluctuating carbohydrate reserves between 'on' and 'off' years, which when low can limit flowering and fruit set. Adjusting fertiliser inputs to higher rates prior to an 'on' year and restricting elements such as nitrogen in an 'off' year can minimise these fluctuations. Avocados are very susceptable to the root rot fungus, *Phytophthora cinnamomi*. Australian research has shown that the activity of this fungus can be suppressed by increasing the calcium status of the soil. Heavy applications of gypsum are standard practice to reduce root rot rather than to improve the nutrient status of the soil. Most of the information included in this section is from research carried out in California, Australia, and South Africa.

PLANT ANALYSIS

Samples for leaf analysis should be collected from mid February to mid April and consist of terminal spring cycle leaves (5-7 months of age) from non-fruiting and non-flushing shoots. At least 50 leaves (blades plus petioles) from the outside of the canopy should be taken at random from 10 or more trees, excluding border trees. Interpretive standards for nutrient concentrations are listed in Table 11.

SOIL TESTING

The ideal soil pH for avocado trees is 5.5 to 6.5. Soil pH values above 7.0 should be avoided as avocado trees are susceptable to Fe deficiency. Deficiencies under these conditions are due to immobilisation rather than inherent deficiency of Fe in the soil. Target soil test values to maintain high production have not been defined for avocado trees grown in New Zealand. Results from a survey of well producing orchards in the Bay of Plenty make it clear that avocado trees tolerate a wide range of macronutrient concentrations in the soil; the ranges in the MAF soil test values were as follows: pH 5.4-6.3; P, 10-135; K, 7-12; Mg, 14-29; Ca, 4-10.

FERTILISER REQUIREMENTS

Maintenance fertiliser applications are listed in Table 12. These rates should be adjusted to meet local requirements and according to the values obtained from regular plant analysis.

Table 11: Standard concentrations for foliar analysis of mature avocados.*

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 1.6	1.6–2.0†	> 2.0
Phosphorus	< 0.05	0.08–0.25	> 0.3
Potassium	< 0.35	0.75–2.0	> 3.0
Calcium	< 0.5	1.0–3.0	> 4.0
Magnesium	< 0.15	0.25–0.8	> 1.0
Sulphur	< 0.5	0.20–0.60	> 1.0
Chloride	–	–	> 0.25–0.5
Micronutrients (ppm)			
Manganese	< 10–15	30–500	> 1000
Iron	< 20–40	50–2000	?
Zinc	< 10–20	30–150	> 300
Copper	< 2–3	5–15	> 25
Boron	< 10–20	50–100	> 100–250

* After Jones and Embleton (1966)
† Optimum for Hass variety, 2.0–2.4%

Table 12: Suggested annual fertiliser applications for maintaining high yielding mature avocado trees and estimated nutrient loss in a 10 tonne/ha crop.

Element	Application Rate kg/ha	Crop Removal kg/ha
Nitrogen	30–150	11.3
Phosphorus	25–50	1.7
Potassium	50	19.5
Calcium	–	2.1
Magnesium	–	5.0
Sulphur	–	8.0
Manganese	–	0.02
Iron	–	0.09
Zinc	–	0.04
Copper	–	0.01
Boron	–	0.04

Compared to other horticultural crops, the quantities of nutrient removed in fruit are low, reflecting the relative low demand of the avocado tree for nutrients. Under New Zealand conditions a yield of between 10-12 tonnes/ha can be expected by the seventh year.

The amount of fertiliser applied depends to a large extent on the age of the tree as the roots are sensitive to excess nutrients, particularly N. Thus for N, only small quantities are required for vigorous growth of young trees, but the quantity increases as the tree begins to bear fruit (Table 13).

Table 13: Annual nitrogen applications for trees of different ages.

Plant age (years)	Application Rate kg/ha
2	12
3–4	25
5–7	50
8–9	75
10–14	100
15 or older	150

For elements such as P larger quantities may be needed at planting to increase the basic level of fertility than when the tree matures.

Fertiliser should be applied in early spring as the demand for nutrients in the tree is highest during flowering and fruit set. However, because of the competition between fruiting and non-fruitng tissues, fertiliser, particularly N, should not be applied any later than six weeks before fruit set.

NUTRIENT DISORDERS

The nutrient disorders which are most likely to affect production in New Zealand are those associated with excess N and chloride, and deficiencies of Zn and B.

Results of surveys of New Zealand orchards have shown the N status of many trees to be well above the optimum range. Under these circumstances N should not be applied until the concentration in the leaves has fallen to more reasonable levels. Excess N can result in reduced yields in some varieties such as Fuerte, largely as a result of excessive vegetative growth at the expense of flowers and fruit set.

Avocado is very sensitive to excess chloride. While chloride toxicity has not been identified as a problem in NZ, areas close to the sea receive large quantities of chloride in airborne sea spray. The most charcteristic symptom of excess chloride is the development of tip and marginal necrosis on mature leaves. In areas where there is the potential for this problem to occur, nutrients such as K should not be applied in the chloride form but rather as the sulphate.

There is some evidence that Zn and B are low in some avocado orchards in NZ. Plant analysis is a very accurate method of diagnosing deficiencies of these two elements. Symptoms of Zn deficiency include, small narrow leaves, interveinal chlorosis, multiple bud development, retention of a rosette of terminal leaves with the remainder dropping giving a 'feather duster effect', twig dieback, and rounded fruit shape. Foliar sprays of Zn (100 g zinc sulphate /100 l have proved to be effective in the short term for correcting deficiencies. In the longer term a combination of foliar sprays plus a soil application of zinc sulphate or zinc chelate is required. In California, soil applications of 1-5 kg/tree have proved to be effective for mature trees.

Symptoms of B deficiency include the gradual death of both the apical and axillary growing points. The leaves are distorted, somewhat crinkled, often lanceolate and have necrotic patches. The midrib and main veins on the lower surface of the leaves frequently split and become corky. An application rate of 5 kg/ha of borax is sufficient to overcome a deficiency. However, care should be taken when applying B as cases of B toxicity of avocado have occurred in New Zealand.

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BABACOS

The babaco (*Carica x heilbornii* Badillo nm. *pentagona* (Heilborn) Badillo) is a perennial shrub of the papaya family found in the subtropical mountainous regions of Ecuador. It was first introduced to NZ in 1973 and is being grown for its unusual fruit.

FERTILISER REQUIREMENTS

Soils should be light and well drained, preferably with large amounts of organic matter incorporated before planting. The soil pH should be raised to between 6 and 6.5.

Babacos probably have a high phosphate requirement and superphosphate (about 1 tonne/ha) should be incorporated before planting. Young trees should be supplied with 100 g of a balanced 6:6:5 NPK fertiliser plus 100 g superphosphate three times a year in September, December and March. Dressings should be increased so that older trees receive 1-1.5 kg of each nutrient element per year. Alternatively, well matured chicken manure can be used, with 5 kg being spread around each tree every couple of months during the growing season.

Nitrogenous fertilisers should be used with caution as excessive N may lead to over vigorous plants and the production of soft fruit which do not handle well.

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CASIMIROAS (WHITE SAPOTE)

The casimiroa (*Casimiroa edulis*) appears to grow best on well drained light soils supplemented with large amounts of organic matter. A good, consistent supply of water is important. In the absence of other information, a citrus fertiliser programme rich in N is probably suitable.

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CHERIMOYAS (CUSTARD APPLE)

Although there have been small commercial plantings of cherimoya (*Annona cherimola*) in NZ in the past little is recorded about its fertiliser requirements under local conditions. All of the information included in this section comes from Queensland and California. It seems that cherimoya will tolerate a wide range of soil types provided they are moderately fertile and free draining. It is also essential that uniform soil moisture is maintained from flowering to harvest.

PLANT ANALYSIS

Leaf samples should be collected towards the end of February or early March. The youngest mature leaf (fourth or fifth leaf back from the growing point) should be selected from actively growing non-bearing shoots.

Critical leaf concentrations for macronutrients and micronutrients have not been determined for cherimoya. The values listed in Table 14 are tentative ranges for healthy plants grown in Queensland and as such should only be used as a guide.

SOIL TESTING

Experience in Queensland indicates that soil analysis is generally less useful than plant analysis for formulating a fertiliser programme for cherimoya. Under their conditions a soil pH within the range of 5.7 to 6.3 is considered to be optimum for maximum production.

Table 14: Typical concentrations for foliar analysis of cherimoyas.

Element	Range
Macronutrients (%)	
Nitrogen	2.5
Phosphorus	0.16–0.20
Potassium	1.0 –1.5
Calcium	0.6 –1.0
Magnesium	0.35–1.0
Sulphur	—
Sodium	0.02
Chloride	0.30
Micronutrients (ppm)	
Manganese	30–90
Iron	40–70
Zinc	15–30
Copper	10–20
Boron	15–40

FERTILISER REQUIREMENTS

During the first four years, the tree is encouraged to produce a large potential bearing area on a strong symmetrically spaced framework. Fertilisers used should have a high proportion of N and be coupled with irrigation to promote vigourous vegetative growth. A tree of moderate to good vigour is usually the best producer; low or excessive vigour is usually associated with low yields. During the first year only N is required where an application rate of 15 to 20 g urea/tree every month from leaf emergence until March is recommended. Fertiliser requirements for trees two years and older are listed in Table 15.

Table 15: Suggested annual fertiliser applications (g/tree) for plants of different ages.

Element	Application Rate Years 2–4*	Over 4 years*
Nitrogen	100	100
Phosphorus	20	20
Potassium	100	150
Sulphur	28	30

* Multiply amounts by age of tree in years to a maximum at 12 years, then maintain.

Nitrogen and K should be applied in split applications, half of the recommended quantities in Table 15 to be applied in October and half in January. Phosphorus and S can be applied in a single application in October.

NUTRIENT DISORDERS

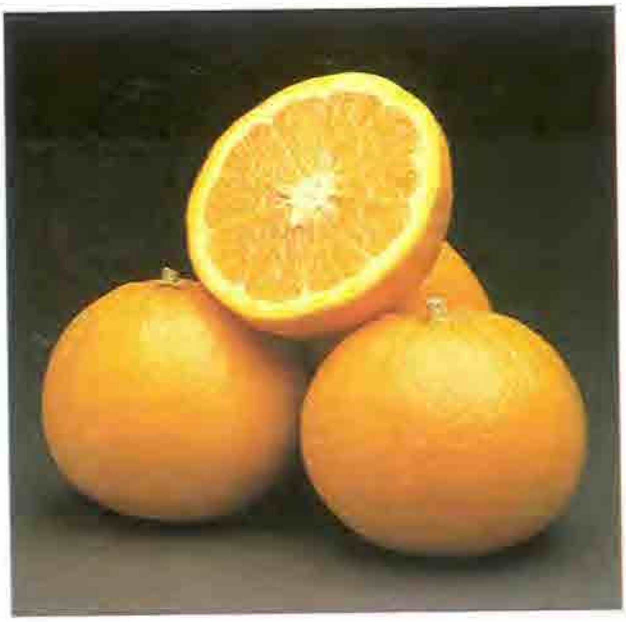
Up to the present time there have been no reports of any nutritional disorders of plants grown in New Zealand. However, it appears that cherimoya have a high requirement for Zn. Zinc deficiency is a common and widespread problem in Queensland. Symptoms of Zn deficiency include restricted terminal growth, small leaves, and interveinal yellowing of leaves. Zinc deficiency has been corrected by applying zinc sulphate ($ZnSO_4.5H_2O$) at a rate of 25 to 30 g/m^2 of soil surface under each tree in a 30 cm wide band just inside the drip line. Foliar sprays have also been used but these have been less effective. Zinc sulphate at a rate of 100 g/100 l is sprayed onto mature leaves in spring. Low levels of Zn are known to occur in soils at Kerikeri.

Boron deficiency is thought to cause a condition in plants in Queensland where hard brown lumps form in fruit, particularly around the seeds. This condition has been corrected by applying 2 g borax/m² of soil surface beneath each tree. Even application and sufficient watering is essential to avoid tree damage. Foliar applications of borax are not as efficient as soil applications but are safer. A mixture of 300 g borax/100 l can be applied to mature spring growth. Although there are a number of soils in New Zealand which are naturally low in B, they are not found in areas where cherimoya are likely to be planted.

FURTHER READING

Dawes, S.N. (1985). Cherimoya — a subtropical fruit with potential. *Growing Today, August:* 18-20, 29.

CITRUS



Minimal pruning is generally carried out on citrus grown in New Zealand, thus the quantity of nutrient which needs to come from soil reserves or fertiliser applications in a cropping orchard, depends on that removed in harvested fruit. Typical fruit yields under New Zealand conditions for Satsuma mandarins and navel oranges range from 20 to 30 tonnes/ha, while yields for valencia oranges and tangelos are slightly higher, 25 to 40 tonnes/ha.

Most citrus grown in New Zealand has a tendency to biennial bearing. During an off year the amount of fertiliser applied should be reduced. In cases of extreme biennial bearing with almost no crop in the off year, as is often the case with Wheeny grapefruit, fertiliser could be eliminated altogether, provided that there were no obvious nutritional disorders apparent.

PLANT ANALYSIS

Samples for leaf analysis should be collected in late February to mid March. The youngest mature leaves on non-fruiting terminals should be selected with each sample consisting of at least 24 leaves taken at random from trees throughout the block. Interpretive standards for nutrient concentrations in the leaves are listed in Table 16.

Table 16: Critical concentrations for foliar analysis of citrus.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 2.4	2.4–2.6	> 3.0
Phosphorus	< 0.10	0.14–0.16	> 0.25
Potassium	< 0.7	0.9–1.2	> 1.7
Calcium	< 2.5	3.0–6.0	> 7.0
Magnesium	< 0.16	0.25–0.6	> 1.2
Sulphur	< 0.14	0.2–0.4	> 0.5
Sodium	–	< 0.16	> 0.25
Chloride	–	< 0.3	> 0.7
Micronutrients (ppm)			
Manganese	< 16	25–200	> 300
Iron	< 36	60–120	> 200
Zinc	< 16	25–100	> 300
Copper	< 3.6	5–10	> 15
Boron	< 15	30–100	> 250

SOIL TESTING

A soil test should be carried out prior to planting. Suggested target MAF levels for adequate nutrition are as follows:

	pH	Ca	K	P	Mg
Most citrus varieties	5.5–6.5	5–8	7–8	40	10–15
Lemons	5.5–6.5	5–8	10–15	40	10–15

The most common commercial rootstock for citrus in New Zealand, *Poncirus trifoliata* does not perform well where the soil pH exceeds 6.5. Under these conditions the uptake of Fe, Mn, and Zn is seriously impaired. Once the orchard is established a routine soil analysis should be taken every year.

FERTILISER REQUIREMENTS

Young trees

Young trees are usually fed on the little and often principle. The approximate quantities of nutrients required by young trees are listed in Table 17.

Table 17: Estimated nutrient requirements (g/tree) for young citrus trees.

Tree Age (years)	Application Rate			
	Nitrogen	Phosphorus	Potassium	Magnesium
1	60	30	25	13
2	120	60	50	26
3	180	90	75	39
4	240	120	100	52
5	300	150	125	65

Fertiliser is usually applied on four separate, but equally spaced occasions beginning in September, and ending in February to coincide with the autumn flush.

Cropping trees

In a mature cropping orchard the minimum quantities which need to be replaced each year from soil reserves or from fertilisers depend largely on the amount removed in harvested fruit. An estimate of these quantities is given in Table 18.

Maintenance fertiliser applications to sustain maximum production. These rates may need to be adjusted to meet local requirements.

Table 18: Estimated quantities of nutrient removed in a 10 tonne crop of citrus.

Element	kg/ha		kg/ha
Macronutrients		Micronutrients	
Nitrogen	29	Iron	0.07
Phosphorus	4	Zinc	0.02
Potassium	63	Copper	0.01
Calcium	26	Boron	0.06
Magnesium	5		
Sulphur	3		
Sodium	5		

Fertilisers are usually broadcast throughout the orchard. Phosphorus and K can be applied in a single application in late winter-early spring. The best time to apply N is to coincide with the start of a growth flush. Most citrus have two growth flushes, one in spring and the other in autumn. As there can be undesirable effects on fruit quality from heavy dressings late in the season, at least two thirds of the annual requirement should be applied in early spring with the remainder in February to coincide with the autumn growth flush. Seminole tangelos are an exception however. Spring N applications should be withheld from this variety until after harvest to prevent excess N from adversely affecting storage quality of fruit.

For lemons, three equal applications to coincide with each growth flush (around September, November and February-March) are recommended.

NUTRIENT DISORDERS

The most common nutrient disorders of citrus in New Zealand are those associated with deficiencies of N, P, Mg, Mn and Zn.

The critical time for N deficiency to occur is just prior to and during flowering, fruit set and December leaf drop. Symptoms of this disorder include yellow coloured foliage, poor flowering, poor yield, and stunted growth. Like most trees however, citrus store N in the woody parts and can utilise this reserve in spring, so a deficiency expressed at that stage could be the result of a shortage created during the previous season. Care should be taken to avoid applying too much N as this can result in poor fruit quality. In particular, it affects fruit colour, delays maturity, reduces juice content, and results in thick skins.

Visual symptoms of P deficiency are not usually seen in NZ but the effects on fruit quality are common in most districts. These include low juice content, thick skins, and acid juice.

Magnesium deficiency is particularly common in years of heavy crops. Symptoms include the yellowing of leaves with an inverted v of green tissue at the base of the leaf. Magnesium deficiency can be corrected by applying 200-400 kg/ha of Mg as Causmag. In severe cases, where an immediate response is required foliar applications containing 1 kg magnesium sulphate plus 1 kg calcium nitrate/100 l can be used.

Manganese deficiency occurs in all citrus growing areas of New Zealand. Symptoms include the development of an interveinal yellowing with a band of darker green along the midrib and veins. Zinc deficiency produces symptoms which are similar to Mn deficiency but the interveinal yellowing is less blotchy and more clearly defined. In extreme cases leaves can be small, narrow, pointed and rosetted in the classical little leaf symptom. Zinc deficiency can also affect fruit shape. Manganese and Zn deficiency often occur together and can be corrected together or singly. The most effective means of correcting both disorders is by foliar sprays. A typical spray mixture consists of 100 g $MnSO_4$, 100 g $ZnSO_4$ and 750 g urea/100 l plus a suitable wetting agent. The urea is helpful for increasing the uptake of Mn and Zn.

Foliar sprays should be applied on their own without the addition of insecticides or fungicides. They should be applied at a time when there is plenty of young foliage, as older leaves are less efficient at absorbing nutrients. Early November, or an equivalent stage in autumn, when the growth flush is about two thirds completed appears to be the most suitable time. Sprays should also be applied in the early morning or in the evening to avoid intense day time temperatures.

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FEIJOAS

The feijoa (*Feijoa sellowiana*) is a native of South America where it is found in high altitude areas of Western Paraguay, Southern Brazil, Uruguay, and parts of Argentina. It appears to be able to tolerate a wide range of climates and soil conditions provided water-logged conditions are avoided. Little is known of the nutritional requirements of feijoas grown in New Zealand, although they are often grown in soils naturally low in plant nutrients. No reliable yield figures are available but values of 25 tonnes/ha have been reported. Most of the nutrient removal in mature orchards is by way of harvested fruit.

PLANT ANALYSIS

Critical leaf concentrations have not been established for feijoas. The values listed in Table 20 are for leaves collected from plants showing no obvious signs of nutritional disorders and as such should only be used as a rough guide to interpreting the results of plant analysis. The leaves were sampled during mid to late summer.

Table 20: Typical concentrations for foliar analysis of feijoas.

Element	Range
Macronutrients (%)	
Nitrogen	1.3 -1.5
Phosphorus	0.06-0.08
Potassium	0.6 -1.0
Calcium	1.5 -2.0
Magnesium	0.2 -0.25
Sulphur	0.12-0.16
Sodium	0.03-0.05
Chloride	-
Micronutrients (ppm)	
Manganese	400-600
Iron	70-100
Zinc	15-20
Copper	2
Boron	40-60

SOIL TESTING

Suggested MAF soil test levels are as follows: pH 5.8-6.8; P, 30; K, 8; Mg, 16; Ca, 8.

FERTILISER REQUIREMENTS

In the first two years after planting, no fruit is carried and light applications of fertiliser are sufficient. After year three, cropping begins and by year 10 the orchard may produce 25 tonnes of fruit/ha or more. By this stage, large inputs of fertiliser will be needed. A tentative fertiliser programme for plants of different ages is given in Table 21.

Table 21: A tentative fertiliser programme for feijoas.

Plant Age (years)	Application Rate kg/ha Nitrogen	Phosphorus	Potassium
1	25	40	20
2	30	40	20
3	45	40	20
4	60	60	80
5	75	80	100
6	90	80	100
7	100	80	100
8	120	80	100

In the first three years fertiliser should be placed around individual trees, but from four years onward broadcast application is satisfactory.

Foliar application of nutrients should be avoided as keeping quality of the fruit has been shown to be adversely affected by this practice.

FURTHER READING

Franklin, S.J. Feijoas. Varieties and culture for commercial production. New Zealand Ministry of Agriculture and Fisheries Aglink, HPP 104.

FIGS

Figs (*Ficus carica*) can produce good crops even under fairly low fertility levels. Soil cultivation should be only superficial otherwise feeding roots will be damaged. Trees are very sensitive to dry soil conditions and regular supplies of water are necessary. Good growth and cropping can be encouraged by mulching about a metre beyond the dripline.

PLANT ANALYSIS

Samples for leaf analysis should be collected in February, and consist of leaves from non-fruiting spurs on spur bearing trees. Interpretive standards for nutrient concentrations are listed in Table 22.

FERTILISER RECOMMENDATIONS

Nitrogen is often the only element that is required but for young trees 100 g of a balanced 6:6:5 NPK fertiliser should be applied every couple of months during the growing season. Applications should be increased so that mature cropping trees, 4-5 m high, are supplied with 7-10 kg of the mixture in late winter/early spring.

Table 22: Standard concentrations for foliar analysis of figs.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 1.7	2.0–2.5	–
Phosphorus	–	–	–
Potassium	< 0.7	1.0	–
Calcium	–	3.0	–
Micronutrients (ppm)			
Boron	< 15	50–100	>300

FURTHER READING

Baxter, P. (1981). The Fig — Varieties and Culture. Agnote Agdex 218/11, Department of Agriculture, Victoria, Australia.

van Zyl, E.J. (1974). Fig Cultivation. Information Bulletin No. 211, Fruit and Food Technology Research Institute, Stellenbosch, South Africa.

GUAVAS

Guavas (*Psidium guajava*) can be successfully grown in a wide range of soils, but they are susceptible to wet feet. Adequate moisture must be supplied, particularly prior to harvest.

FERTILISER REQUIREMENTS

Young trees should be supplied with 150–500 g 6:6:5 NPK balanced fertiliser every couple of months during the growing season, the amounts increasing with age. Older trees should be given about 500 g 6:6:5 NPK balanced fertiliser per cm of stem diameter, the application being split between spring and summer. Heavy bearing trees should be supplied with extra N shortly before flowering.

FURTHER READING

Malo, S.E. and Campbell, C.W. (1968). The Guava. Fruit Crop Facts Sheet No. 4, Florida Agricultural Extension Service, University of Florida, USA.

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KIWIFRUIT

Kiwifruit (*Actinidia deliciosa*) is a vigorous growing vine. In its natural habitat in the mountainous regions of central and southern China it is found growing in deep humus-rich soils on the sides of steep gullies. In NZ kiwifruit have been successfully grown on a wide range of soil types, but it yields best on well drained soils which are not prone to waterlogging or likely to dry out too quickly in the summer. Kiwifruit have an extensive root system which in mature orchards may overlap with that from vines in adjacent rows. Recent results have also shown that a large proportion of their roots are close to the surface of the soil, although some roots may penetrate the soil to considerable depths. However, in soils with unfavourable characteristics such as those with compacted iron pans or which are heavy and poorly draining, the root system may be restricted close to the surface. The distribution of the root system will dictate whether fertiliser should be spread evenly throughout the orchard or banded close to the plant. As 50% of the root system needs to be exposed to the fertiliser to be effective, broadcast methods of application should generally be used in preference to banding methods.

PLANT ANALYSIS

Leaf samples for monitoring the nutrient status of the vine should be taken at the same physiological stage of growth each year. That is, time of sampling should be measured in terms of weeks after budbreak rather than on a strict calendar basis. Leaves should be collected early in the season for chemical analysis. Prior to fruit set the youngest fully expanded leaves on current season's canes should be taken. However, if samples are to be collected after fruit set then the second leaf past the final fruit cluster on a fruiting cane should be taken. In both cases leaves from at least 20 vines (two to three leaves per vine) should be collected within the area of the orchard to be monitored. Tentative standards for assessing the nutrient status of kiwifruit leaves sampled mid season are given in Table 23.

Because of the marked seasonal changes that occur in nutrient concentrations in leaves, optimum concentrations for assessing nutrient status early in the season (Table 24) differ from those recorded during February.

Sampling leaves for diagnostic purposes is largely independent of the time during the growing season. Leaves (blades plus petioles) showing distinctive symptoms should be collected as soon as they appear on the affected vines. At the same time a second sample of leaves should also be collected from an identical position on healthy non-affected plants nearby. By taking an affected and an unaffected sample the results can be compared directly and possible disorders identified without having to rely upon standard values.

Table 23: Standard concentrations for foliar analysis of kiwifruit leaves sampled in February.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 1.5	2.2 – 2.8	> 5.5
Phosphorus	< 0.12	0.18–0.22	> 1.0
Potassium	< 1.5	1.8 – 2.5	–
Calcium	< 0.2	3.0 – 3.5	–
Magnesium	< 0.1	0.3 – 0.4	–
Sulphur	< 0.18	0.25–0.45	–
Sodium	–	0.01–0.05	> 0.12
Chloride	< 0.6	1.0 – 3.0	> 7.0
Micronutrients (ppm)			
Manganese	< 30	50–100	> 1500
Iron	< 60	80–200	–
Zinc	< 12	15–30	> 1000
Copper	< 3	10–15	–
Boron	< 20	40–50	> 100

Table 24: Standard concentrations for foliar analysis of kiwifruit leaves sampled four weeks after leaf emergence.

Element	Optimum Range
Macronutrients (%)	
Nitrogen	3.5 – 3.9
Phosphorus	0.6 – 0.7
Potassium	2.65–2.75
Calcium	1.35–1.45
Magnesium	0.30–0.35
Sulphur	0.50–0.55
Micronutrients (ppm)	
Manganese	85– 95
Iron	115–150
Zinc	55–70
Copper	20–30
Boron	18–30

SOIL TESTING

There is no definitive information for kiwifruit at present on the optimum nutrient levels in soils. In the absence of well defined target levels for each nutrient in the wide range of soil types on which kiwifruit are grown it would seem that the presence of healthy high yielding vines should be the ultimate arbiter as to whether or not soil conditions are optimum for growth. Soil tests should be carried out before planting and each succeeding year with the aim of monitoring and correcting trends in nutrient levels in the soil rather than in the pursuit of attaining particular soil values.

Recent results show that kiwifruit tolerate a wide range of macronutrient concentrations in the soil, but inconsistencies relating to soil type do occur. For example, kiwifruit have been observed growing vigorously at pH values as low as 4.5 on peat soils and as high as 6.8 on calcareous alluvial soils at Gisborne and Hastings, yet a pH of 5.2 on Ohaupo silt loam has resulted in Mn toxicity.

FERTILISER REQUIREMENTS

Precise information from fertiliser trials on the quantity of nutrients needed to maintain maximum production and to correct specific nutrient disorders is currently lacking for kiwifruit grown in NZ. However, estimates of the removal of nutrients in fruit and prunings give some guide as to the minimum quantities which must be replaced each year from reserves in the soil or from fertiliser additions. For some elements such as K the quantities that need to be replaced are large. The estimated annual removal of nutrients in fruit from a mature orchard producing 25 t/ha is given in Table 25.

Table 25: Tentative annual fertiliser requirements for maintaining maximum yields on established kiwifruit vines and the estimated nutrient loss in a 25 tonne/ha crop.

Element	Application Rate kg/ha	Crop Removal kg/ha
Nitrogen	100–150	46
Phosphorus	60	6
Potassium	250–300	80
Calcium	–	8
Magnesium	50	4
Sulphur	60	5

While generalised maintenance fertiliser recommendations can be based on the quantities of nutrients removed from the orchard in fruit, they may not be sufficiently accurate to prevent nutrient disorders arising in every situation. For example, additional inputs will be needed if prunings, either winter or summer, are also removed from the orchard. Furthermore in young orchards, additional nutrients will be required for extension of the vine framework. Therefore it is important to monitor closely the nutrient status of the crop with soil and plant analysis. Results from analysis of leaf samples collected from different parts of the plant every two weeks from budbreak until leaf fall show that for elements such as N, P and K, the period of greatest uptake occurs during early leaf growth up to fruit set. Thus it is essential that fertilisers be applied early in the season (August-September).

NUTRIENT DISORDERS

Nutritional disorders are common in kiwifruit grown in NZ. Such disorders have resulted in serious reductions in fruit production and in some cases affected the storage quality of the fruit. Common disorders ranked according to the frequency with which they occur in the field are as follows:

Deficiencies:	K, Mg, N, Mn, Zn
Toxicities:	B, Na, Mn

Potassium deficiency (K< 1.5%) is by far the most widespread disorder. In many cases the distinctive leaf symptoms associated with K deficiency have been incorrectly attributed to drought stress and wind damage. The first signs of the disorder include poor growth at bud break. As the deficiency becomes more pronounced there is an upward rolling of the margins of the older leaves which is particularly noticeable during the warmer periods of the day. This symptom may disappear overnight only to reappear the following day. Eventually, the leaf margins remain permanently rolled. Later in the season large areas of tissue die giving the leaf a scorched appearance as the affected tissues dry out. Inadequate applications of K fertiliser to compensate for K required in new cane and leaf growth, and for the large annual removal in fruit, largely accounts for the high incidence of this disorder. Competition from grasses and clover can also enhance a deficiency of K. To correct a moderate to severe deficiency in a mature orchard expected to produce 25 tonnes/ha plus grow an extra 40 metres of cane per vine, an input of at least 250–300 kg/ha of K (500–600 kg/ha of potassium chloride) would be required. Potassium chloride should be used in preference to potassium sulphate.

Magnesium deficiency (Mg< 0.1%) is relatively widespread. Symptoms include a pale yellow-green interveinal chlorosis of the older leaves. The chlorosis usually develops at the leaf margin and spreads inwards between the veins towards the midrib, often leaving a relatively wide zone of healthy tissue each side of the main veins and at the base of the leaf. Initially, there is no necrotic tissue associated with the chlorosis, but as the deficiency becomes more pronounced the chlorotic tissue turns bright yellow and a marginal or interveinal necrosis may develop. Symptoms of Mg deficiency are not usually observed until February and then only on the older leaves of the current season's extension canes. To correct a moderate to severe deficiency an input of at least 100–200 kg Mg/ha is required.

Symptoms of N deficiency (N < 1.5%) develop first on the older leaves and spread progressively to young leaves until the whole plant is affected. Initially, there is a gradual change in the colour of the leaf from the usual dark green to light green. On severely deficient plants the veins remain conspicuously green. Without regular annual applications of N fertilisers, most horticultural soils in NZ which are cropping regularly will sooner or later become deficient in this element.

Manganese deficiency (Mn< 30 ppm) produces a light green-yellow interveinal chlorosis which appears first on recently matured leaves but in severe cases it may affect almost all leaves on a plant. As the deficiency becomes more pronounced, the zone of healthy tissue recedes even further towards the veins so that eventually only the veins remain green. Leaf size is not noticeably reduced nor is there any necrosis of the leaf tissue. Manganese deficiency is widespread in parts of Gisborne and Hawkes Bay, and is usually associated with soils where the pH exceeds 6.8. In most cases Mn deficiency can be corrected readily by applying sufficient quantities of compounds which will acidify the soil thereby releasing previously unavailable manganese to the plant. Such acidifying compounds include finely ground elemental S, aluminium sulphate, or ammonium sulphate.

Zinc deficiency (Zn< 12 ppm) of kiwifruit has been observed in orchards on the Waimea Plains near Nelson, at Motueka, Wanganui and near Hastings. Low levels of Zn also occur in soils at Kerikeri, but there is no evidence yet of a deficiency in kiwifruit grown on these soils. Symptoms of this disorder include a bright yellow interveinal chlorosis on the older leaves with the veins remaining dark green. Foliar sprays or soil applications of zinc salts must be applied prior to leaf emergence or shortly after if these methods are to be effective in correcting the deficiency.

As with other B sensitive plants the margin between B sufficiency and toxicity is very narrow for kiwifruit. Concentrations of B in the leaves only slightly above the required level can cause serious injury to the plant. Early symptoms of B toxicity (B >100 ppm) include a yellow-green interveinal chlorosis developing first on the older leaves and spreading progressively to the younger leaves. It is also usual to find the affected leaves cupped either upwards or downwards. As the toxicity becomes more pronounced, the interveinal chlorosis quickly gives way to small patches of necrotic tissue which develop between the minor veins and extend to the midrib. Eventually, the necrotic patches link up forming a continuous zone of dead tissue between the major veins. As this necrotic tissue weathers it changes from brown to a silvery-grey colour. By this stage the necrotic tissue has become very brittle and may break away giving a ragged appearance to the leaf. In NZ B toxicity has been observed following heavy applications of B fertiliser to the soil (in excess of 2 kg B/ha), as a result of foliar sprays, or where bore waters naturally high in B (>0.8 mg/l) have been used for irrigation.

Excess Na in bore waters (Na>100 mg/l) has damaged kiwifruit in the Bay of Plenty and Gisborne. In the field kiwifruit affected by excess Na are typically stunted with small, dull bluish-green leaves. Wilting symptoms are seldom observed. It appears that kiwifruit effectively exclude Na from the aerial tissues as the concentration in leaves of affected plants are always less than 0.12% DM. As with other plant species the mechanisms whereby Na interferes with the metabolism of the plant are not well understood.

Manganese toxicity (Mn > 1500 ppm) can be distinguished from other nutritional disorders by the appearance of a regular pattern of small black spots which concentrate along the main veins on the older leaves. Manganese toxicity is nearly always associated with acid soils and/or poorly drained soils. This disorder can be corrected by application of lime which increases soil pH and reduces the solubility of Mn, and by improvement of drainage in the orchard.

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LOQUATS

Little is known about the nutritional requirements of loquat (*Eriobotrya japonica*) so a fertiliser mix, rich in N, and similar to that used for citrus, could be applied in several applications per year to young trees. Older trees should be supplied with 6-9 kg of a balanced 6:6:5 NPK fertiliser, two thirds before flowering in late autumn/early winter, the remainder after flowering.

FURTHER READING

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LYCHEES (LITCHI)

Lychees (*Litchi chinensis*) could be grown only in the warmest parts of NZ. For best growth they require abundant moisture.

PLANT ANALYSIS

Samples for leaf analysis consist of the middle pair of leaflets from the second composite leaf located behind the fruiting stalk and towards the stem. These should be collected 6-10 weeks prior to harvest. The range of nutrient concentrations expected in healthy tissue sampled at this time of year are given in Table 26.

Table 26: Typical concentrations for foliar analysis of lychees.

Element	Range
Macronutrients (%)	
Nitrogen	1.5 -2.0
Phosphorus	0.1 -0.3
Potassium	0.7 -1.4
Calcium	0.5 -1.0
Magnesium	0.25-0.60
Sodium	< 0.10
Micronutrients (ppm)	
Manganese	40-400
Iron	25-200
Zinc	15-25
Copper	5-20
Boron	15-50

FERTILISER REQUIREMENTS

Young trees should be supplied with 100-200 g of a 6:6:5 NPK fertiliser every couple of months during the growing season. By the third year, trees should be supplied with about 1 kg of such a mix per year for every 2.5 cm of trunk diameter. Similar programmes should be suitable for larger plants.

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MACADAMIAS

Macadamias are indigenous to the coastal rainforests of Southern Queensland and Northern New South Wales but were first developed commercially in Hawaii during the early 1920s. Two main species are cultivated commercially for their nuts, *M. integrifolia* and *M. tetraphylla*. The former species has round, smooth-shelled nuts, creamy-white flowers and young vegetation that is pale green or bronze. In contrast *M. tetraphylla* has peeble surfaced nuts, pink flowers and immature leaves which have a purple or reddish colouration. As its name suggests *M. tetraphylla* nodes commonly carry four leaves as opposed to three for the *integrifolia* species.

Macadamias grow best in a subtropical environment and in NZ may be grown in areas suitable for avocado and citrus. Both species appear to crop equally well here. *Tetraphylla* varieties however appear to be more suitable for production of fresh nuts and have fewer establishment problems than *integrifolia* varieties, which, because of their higher oil content, are preferable for processing.

There is minimal information available concerning the nutrient requirements of macadamias under NZ conditions. The information presented here is based on research in Australia and Hawaii.

PLANT ANALYSIS

Fertiliser programmes based on leaf analysis have been found to be accurate and useful for predicting the nutrient requirements of trees growing on different soil types in Hawaii. The standard procedure for plant analysis consists of taking leaves from the most recently matured terminal. Usually these will be the group of leaves at the second node back from the growing tip. New terminals continue to develop throughout the year and can be easily identified in that the leaves are a glossier green than older leaves. Care should be taken however to ensure that leaves are not selected from terminals that have not fully matured; immature leaves have a distinctly softer feeling. Each sample should consist of approximately 50-100 leaves selected at random from throughout the property.

Table 27: Standard concentrations for foliar analysis of macadamias (*Integrifolia* sp.).*

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 1.3	1.3 -1.5	> 1.6
Phosphorus	< 0.06	0.07-0.08	> 0.11
Potassium	< 0.40	0.45-0.65	> 0.8
Calcium	< 0.4	0.60-0.90	-
Magnesium	< 0.06	0.08-0.11	-
Sulphur	< 0.18	0.18-0.25	-
Sodium	-	0.01-0.04	-
Micronutrients (ppm)			
Manganese	< 10	100-1000	> 1500
Iron	< 20	20-200	-
Zinc	< 10	15-50	-
Copper	< 3	5-10	-
Boron	< 20	40-75	> 100

* Based on Shigeura and Ooka (1984).

Standards for chemical analysis of macadamia leaf tissue are listed in Table 27. As the leaves being sampled are always of the same physiological age the nutrient concentrations listed are applicable to samples taken at any time during the summer season. Analysis values for *tetraphyllas* can be based on those for *integrifolia* although adjustments may need to be made depending on responses in production and nut quality to fertiliser additions.

SOIL TESTING

There are no optimum soil test levels suggested for macadamias grown in this country. Conflicting opinions exist as to what the most favourable pH range is for production in Australia. Suggested values range between 5.5-6.9. However, as most of the NZ plantings are centered on the volcanic soils around Kerikeri, a pH range of 5.5-6.5 would be more reasonable to avoid reducing the availability of Zn which is already low in these soils.

FERTILISER REQUIREMENTS

Macadamias are sensitive to excess fertiliser, particularly phosphate. The management practices suggested encourage fertiliser applications to be split into three and applied about July, December and February prior to seasonal growth flushes. This strategy avoids plant damage due to large single applications of fertiliser (young trees are very susceptible to fertiliser burn) and ensures nutrient availability throughout growth.

For young trees it is suggested that NPK fertiliser (12:2:13) be used at an annual rate of 500-600 g/tree/year of age, up to a maximum age of 10 years (DPI,1979). This should be split and applied in a number of small applications. Broadcast rates of 150-200 kg N/ha, 40-60 kg P/ha and 50-100 kg K/ha are recommended for mature trees, the rate being split into three and applied as outlined above.

NUTRIENT DISORDERS

It is particularly important to monitor the P status of macadamias with leaf analysis. It is evident from Hawaiian research that the margin between P deficiency ($P<0.06\%$) and P excess ($P>0.11\%$) is quite narrow, and that deficiencies of Fe, Mn or Mg may be induced following heavy applications of P fertiliser.

Leaves below the terminal in the top third of P deficient trees defoliate. The remaining leaves at the apex are small, while those on the lower third of the tree are larger and healthy in appearance. Such trees require immediate phosphate fertilisation and will respond with time.

The K requirements of macadamia are low relative to other crop species. Symptoms of K deficiency ($K<0.05\%$) are restricted to older leaves which have a marginal necrosis.

Boron deficiency ($B>20$ ppm) is quite prevalent in Hawaii. Symptoms include dieback of the terminals, which show clusters of small leafy heads, and subterminal defoliation. Application of soluble B sources to affected trees results in regrowth throughout the defoliated areas and at the terminals. There are soils within NZ where crops require, and show responses to extra B, however these are in areas where the climate is unsuited to macadamia production. Deficiency symptoms of Fe, Zn, Mg and N are similar to those in other crop species (see Introductory Section for symptoms of nutrient deficiencies).

FURTHER READING

Dawes, S.N. (1981). Macadamias. Varieties and culture for commercial production. New Zealand Ministry of Agriculture and Fisheries Aglink, HPP 244.

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Massey, W. (1985). Which way will the nut crack? *Southern Horticulture, 21:* 18-21.

Shigeura, G.T. and Ooka, H. (1984). *Macadamia Nuts in Hawaii: History and Production.* Research Extension Series 039, College of Tropical Agriculture and Human Resources, University of Hawaii, USA, pp. 91.

OLIVES

Although olives (*Olea europaea*) will grow and produce fruit even on extraordinarily poor stoney soils they do respond to fertilisers. They are shallow rooted and cultivation should be kept to a minimum.

PLANT ANALYSIS

Samples for leaf analysis should be collected in February and consist of fully expanded basal to mid shoot leaves. Interpretive standards are listed in Table 28.

Table 28: Standard concentrations for foliar analysis of olives.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	<1.4	1.5–2.0	–
Phosphorus	–	–	–
Potassium	<0.4	0.8	–
Calcium	–	1.0	–
Magnesium	–	0.10	–
Sodium	–	–	>0.2
Chloride	–	–	>0.5
Micronutrients (ppm)			
Boron	14	19–150	>185

FERTILISER REQUIREMENTS

The following recommendations are based on the programmes for South African and Californian conditions. Before planting, large amounts of organic matter should be incorporated into the soil.

At planting, 1.5 kg 15% potassic superphosphate and 0.5 kg ammonium sulphate can be mixed well with the soils replaced in the holes (ie, about 100 g N, 120 g P, 100 g K).

For trees one to four years of age 1.5 kg 15% potassic superphosphate and 0.5 kg urea should be broadcast under trees; two thirds in August before the spring flush of growth, one third at flowering (ie, about 250 g N, 120 g P, 100 g K).

Once trees begin to bear 3.0 kg 15% potassic superphosphate and 0.5 kg urea should be broadcast evenly under trees, in split applications as above (ie, about 500 g N, 240 g P, 200 g K).

FURTHER READING

Castiglione, C. and Glommaert, K.L.J. (1971). Olive Growing. Information Bulletin No. 53, Fruit and Food Technology Research Institute, Stellenbosch, South Africa.

Beutel, J., Uriu, K, and Lilleland, O. (1978). Leaf analysis for California deciduous fruits. In: *Soil and Plant — Tissue Testing in California.* (Reisenauer, H.M., Ed), University of California, USA, pp. 11-14.

PASSIONFRUIT (PURPLE GRANADILLA)

Passionfruit (*Passiflora edulis*) tolerate a wide range of soil types provided they are free draining. Such conditions are essential to minimise the risk of root canker which is a complex disease resulting from a combination of *Phytophthera*, *Fusarium*, and *Verticillium*. The root system is extensive but shallow, and as such is easily damaged and may also be subjected to intense competition from weeds. In New Zealand fruit yields average from 10 to 17 tonnes/ha, but values of up to 45 tonnes/ha have been recorded.

PLANT ANALYSIS

Leaf samples for analysis should be taken in September prior to fertilisers being applied. The youngest fully mature leaf on well developed, actively growing laterals should be selected, with each sample consisting of at least 20 leaves taken from vines randomly selected throughout the orchard.

Standard leaf concentrations given in Table 29 are based on Australian figures. Copper leaf concentrations may be much higher in NZ, often around 250 ppm, due to the presence of residues from copper sprays used to control both fungal and bacterial diseases.

Table 29: Typical concentrations for foliar analysis of passionfruit.

Element	Low	Optimum	High
Macronutrients (%)			
Nitrogen	< 4.75	4.75–5.25	> 5.25
Phosphorus	< 0.25	0.25–0.35	> 0.35
Potassium	< 2.0	2.0 –2.5	> 2.5
Calcium	< 0.5	0.5 –1.5	> 1.5
Magnesium	< 0.25	0.25–0.35	> 0.35
Sodium	< 0.1	0.1 –0.2	> 0.2
Chloride	< 0.6	0.6 –1.6	> 1.6
Micronutrients (ppm)			
Manganese	< 50	50–200	> 200
Iron	< 100	100–200	> 200
Zinc	< 45	45–80	> 80
Copper	< 5	5–20	> 20

SOIL TESTING

Target MAF soil test values have not been determined for passionfruit grown in New Zealand. However, a soil pH of 5.5 to 6.5 is recommended for Australian conditions.

FERTILISER REQUIREMENTS

Under ideal conditions passionfruit is a vigorous and heavy bearing vine. To maintain high production large quantities of fertilisers are needed (Table 30).

The fertiliser should be applied in two dressings, one half in September and the balance in late November, early December. In the first year the following quantities are recommended: 75-100 kg N; 30 kg P; 30 kg S and 100 kg K/ha. In all cases fertiliser should be spread over the entire area between the trellises.

Table 30: Maintenance fertiliser requirements for mature passionfruit vines, and estimated nutrient removal in a 15 tonne/ha crop.

Element	Application Rate kg/ha	Crop Removal kg/ha
Nitrogen	150–200	50
Phosphorus	30	6
Potassium	200	15
Sulphur	30	4

NUTRITIONAL DISORDERS

The nutritional disorders which are most likely to affect production are those associated with excess N, and deficiencies of Zn and Mn.

Research overseas has shown plants that are growing luxuriantly but yielding poorly may be receiving too much N. In such cases a reduction in the amount of N applied while increasing that of P and K has resulted in increased production.

Zinc deficiency is relatively common in passionfruit. Symptoms include small leaves, distorted growing tips and yellow interveinal mottling of younger leaves. A foliar spray consisting of 100 g zinc oxide (ZnO) plus 300 g urea/100 l applied in spring when the new growth is a few weeks old, has been found to be effective.

Manganese deficiency is common in vines grown on calcareous and other high pH soils (pH 7.0) such as those found in the Poverty Bay and Hawkes Bay areas. Foliar sprays with manganese sulphate (500 g/100 l) may be used but a more effective measure is to treat the soil with an acidifying compound such as ammonium sulphate, finely ground elemental S, or aluminium sulphate.

FURTHER READING

Clark, C.J. and Smith, G.S. (1984). pH-induced manganese deficiency. Possible methods of correction. *Southern Horticulture, 18*: 21-23.

Fletcher, W.A. (1973). *Passionfruit Growing*. Bulletin No. 135, New Zealand Ministry of Agriculture and Fisheries, Government Printer, Wellington, pp. 24.

Yerex, D. (1983). Passionfruit. Yet another chance. *Southern Horticulture, 12*: 45-47.

PERSIMMONS (KAKI)

Persimmons (*Diospyros kaki*) are a new commercial crop in NZ, although isolated trees have long been grown in home gardens in various parts of the country. Most of these plants are astringent whereas non-astringent cultivars are now recommended for orchards. The fertiliser practices and nutritional requirements adopted for commercially grown persimmons in NZ are essentially based on those evolved in Japan under different management regimes, and on soil types that differ from our own. An investigation of the nutritional requirements of persimmons grown under our own conditions is currently being undertaken at Ruakura.

PLANT ANALYSIS

Leaf samples for chemical analysis should be collected approximately two months prior to harvest. In NZ this corresponds to the late February-March period. Between 25-50 youngest mature leaves should be obtained from non-fruiting extension shoots on trees selected at random (omitting pollinators) throughout the orchard. In young blocks prior to fruit production, youngest mature leaves should be selected from the most recent vegetative growth. This is generally growth which has occurred during summer flush and has a lighter green colouration than the older leaf material produced in spring.

The nutrient concentrations listed as 'optimum' (Table 31) are provisional, being derived from limited surveys of Fuyu blocks in orchards at Te Puke and in the Waikato. Those defining deficiency arise from orchard surveys and sand culture studies done in Japan. Much of this information can be expected to be refined as our experience with persimmons increases.

SOIL TESTING

Persimmons grow on a wide range of soil types, but prefer deep, fertile, well drained soils. They can grow on clay soils if well drained, or on lighter sandy soils if well irrigated.

The general fertility levels of soil should be adjusted before planting. Adjustment of pH is particularly important in this regard. Persimmons require a pH between 6-6.5; preferably closer to 6.5. As this plant develops a large tap root (development of an extensive network of lateral roots does not seem to occur in some of our soils), it is important to influence the pH at depth. This is most easily done prior to planting.

Soil testing should be done annually at the same time of year. Samples should be taken about 1.5 m out from the trunk in the herbicide strip. It is suggested that samples be taken at two depths, 0-20 and 20-40 cm; the latter sample to check soil pH in this zone.

There are no optimum MAF soil test levels available for this crop. Orchards containing healthy trees in the Pukekohe area have average levels (0-20 cm) of Ca, 10; K, 19; P, 66; and Mg, 21. These can only be regarded as a guide and should be expected to differ in other regions such as Gisborne, for example, where naturally occurring levels of K, Mg and Ca routinely exceed these.

FERTILISER REQUIREMENTS

Persimmons take about 10 years to reach full cropping and the fertiliser programmes should be increased accordingly.

Young trees

Year 1: A balanced NPK fertiliser should be spread around each plant providing it with 50 g N, 50 g P, 50 g K/tree in three applications: half in late dormancy (end of August), a quarter in mid October, and the remaining quarter at the end of December. Most formulations will supply sufficient Mg (25 g Mg/tree).

Years 2-5: Each year the application should be increased so that by year five each tree is being supplied 200 g N, 150 g P, 200 g K and 100 g Mg. Applications can then be reduced to two a year. As the trees start cropping the relative supplies of potassium are increased.

Mature trees

Fertilisers (Table 32) should be broadcast in two dressings in spring (late August) and summer (late December). These

Table 31: Standard concentrations for foliar analysis of persimmons (Fuyu)*.

Element	Deficient	Optimum
Macronutrients (%)		
Nitrogen*	< 0.93	1.57–2.00
Phosphorus	< 0.05	0.10–0.19
Potassium	< 0.42	2.40–3.70
Calcium*	< 0.26	1.35–3.11
Magnesium	< 0.13	0.17–0.46
Sulphur	–	0.21–0.44
Sodium	–	0.01–0.02
Micronutrients (ppm)		
Manganese	< 27	238–928
Iron	–	56–124
Zinc	–	5–36
Copper	–	1–8
Boron	–	48–93

* This data is based on analysis of tissue from fruiting trees; Ca concentrations in tissue from young non-fruiting trees are likely to be lower than these values (≈ 1.2%), with N somewhat higher (≈ 2.2%).

applications are somewhat lower than those used in Japan, but recommendations will probably be modified with experience in this country. In Japan, more N is supplied to trees growing on heavy clay soils, less P to trees in sandy soils.

NUTRIENT DISORDERS

To date, nutrient disorders observed in NZ grown persimmons are restricted to deficiencies of Mg, Mn, Ca and Fe; the former two in orchards, the latter common in seedlings grown in planter bags.

Table 32: Suggested fertiliser recommendations for mature persimmon orchards and nutrient removal in a 25 tonne/ha crop.

Element	Application Rate kg/ha		Crop Removal kg/ha
	Spring	Summer	
Nitrogen	100	25	21
Phosphorus	70	–	6
Potassium	100	25	45
Calcium	–	–	5
Magnesium	70	–	1.8
Sulphur	–	–	2.5

The leaf symptoms for Mg deficiency ($Mg < 0.13\%$) are similar to those for other crops. At this stage it seems that Hospital Fuyu may be more susceptible to this deficiency; necrotic tissue appearing in the interveinal regions of the young summer growth about March. Soil applications of soluble Mg sources at a rate of 200 kg Mg/ha or several foliar sprays containing 1-2 kg $MgSO_4$/100 l are effective.

Manganese deficiency ($Mn < 27$ ppm — see Introductory Section for symptoms of nutrient deficiencies) has been observed on calcareous alluvial soils in Poverty Bay when the pH exceeds 7.0. Correction by application of acidifying compounds to lower the soil pH is preferable; however, foliar applications of $MnSO_4$ in spring (300 g $MnSO_4$ plus 400 g hydrated lime/100 l — repeated at 10 day intervals if necessary) will control the deficiency on a seasonal basis.

Leaves with Ca deficiency ($Ca < 0.26\%$) are excessively puckered and crinkled, particularly near to the leaf apex. Soil applications of soluble forms of Ca such as calcium nitrate should alleviate this deficiency.

The most severe and widespread disorder however is Green Blotch, a problem brought about by excess manganese (or inadequate Ca) which creates a Ca/Mn imbalance within the fruit. Although the concentration of Mn in leaves may be elevated ($Mn > 1000$ ppm) symptoms of the disorder are confined to the fruit only. Indeed, concentrations of Mn as high as 6800 ppm have been observed without symptoms of Mn toxicity being present in leaf tissue. Prominent green blotches appear at the distal end of affected fruit in mid March. If the blotches have not disappeared by harvest, as can occur, the appearance of the fruit makes it unsuitable for export even though the interior flesh remains unaffected.

Corrective measures, while simple in theory, have not proved to be entirely satisfactory. Increasing the pH to 6.5, particularly at depth, is necessary to both increase Ca, and to decrease the availability of Mn. Alternatively, if the pH is already adequate addition of gypsum ($CaSO_4$) is advocated. Foliar sprays of calcium nitrate applied around fruit-set may assist in correcting Green Blotch. At present however the concentration, number of sprays, and their timing is still experimental.

FURTHER READING

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Clark, C.J. and Kajiura, I. (1986). Nutritional disorders in persimmons. *Growing Today, April issue*.

Clark, C.J. and Smith, G.S. (1985). pH-induced manganese deficiency. Possible methods of correction. *Southern Horticulture, 18*: 21-23.

Clark, C.J. and Smith, G.S. (1986). Leaf analysis of persimmons. *Growing Today, February*: 15-17.

Kitagawa, H, and Glucina, P.G. (1984). *Persimmon Culture in New Zealand*. NZ DSIR Information Series No. 159, Science Information Publishing Centre, Wellington, pp. 74.

TAMARILLOS

Little research has been carried out in NZ on the nutrient requirements of tamarillos (*Cyphomandra betacea*). However, to maintain maximum production of good quality fruit it has been found that fertiliser, particularly N, needs to be applied periodically throughout the entire growing season. The reason for this need is that fruit is set in trusses (similar to a tomato) continuously throughout the season. Vegetative growth is also continuous. Tamarillos come into production quickly, and a half crop can be carried in the second year from planting with a full crop in the third year. Under suitable conditions tamarillos can yield from 15 to 17 tonnes/ha in commercial orchards.

PLANT ANALYSIS

Critical leaf concentrations for tamarillos have not been determined. The values given in Table 33 are for leaves collected in January-February from plants showing no obvious signs of nutritional disorders and as such should only be used as a rough guide for assessing the nutrient status of leaves. The leaf sample consisted of the youngest fully expanded leaf (plus petiole) from vigorously growing shoots.

FERTILISER REQUIREMENTS

Tentative maintenance fertiliser additions for mature plants are given in Table 34.

The chemical composition of the leaves suggests that the requirements for K could be higher than those given in Table 34. However, close monitoring of the plant with leaf analysis will indicate whether the rates should be adjusted to meet local requirements.

Phosphorus and K are usually applied in early spring, but N is applied in several dressings throughout the season. For trees pruned in September or October, three equal applications are made: the first at pruning time, and the other two in November and February. If pruning is delayed as late as November or even December, the first two applications should be combined and applied at pruning time with the third being given in February. Nitrogen should not be applied to dry soil or when plants are suffering from drought stress as further damage could occur.

Soil pH should be maintained at 6.0. At planting 400-500 g of blood and bone or other mild organic fertilisers should be added to the planting hole.

Table 33: Typical concentrations for foliar analysis of mature tamarillo plants.

Element	Range
Macronutrients (%)	
Nitrogen	3.56–4.37
Phosphorus	0.22–0.32
Potassium	5.0 –6.0
Calcium	1.1 –2.7
Magnesium	0.32–0.42
Sulphur	0.27–0.37
Sodium	0.02–0.06
Micronutrients (ppm)	
Manganese	80–150
Iron	100–150
Zinc	24–32
Copper	19–23
Boron	20–30
Molybdenum	0.2–1.0

Table 34: Annual maintenance fertiliser requirements of tamarillos and estimated nutrient removal in a 16 tonne/ha crop.

Element	Application Rate kg/ha	Crop Removal kg/ha
Nitrogen	110-170	48
Phosphorus	35–55	6
Potassium	80-100	51
Magnesium	20–50	3

NUTRIENT DISORDERS

Although the symptoms of nutrient disorders of tamarillos are not well documented instances of deficiencies of most macronutrients, especially N, K, and Mg have occurred in NZ, along with deficiencies of Zn and Mn.

FURTHER READING

Sale, P.R. (1983). Tamarillos. Orchard management. New Zealand Ministry of Agriculture and Fisheries Aglink, HPP 297.

Sale, P.R. (1985). Management aspects of tamarillos. *New Zealand Fruit and Produce Journal, Sept/Oct:* 17-20.

(R.E. Smart, A.D. Clarke, S.J. Wheeler)

GRAPEVINES

Among horticultural plants, grapevines are acknowledged as having less exacting nutritional requirements. They can be grown on a wide range of soil types, but nutritional problems show most commonly on lighter textured soils. Most established vineyards in New Zealand are on medium to heavier textured soil, with the exception of Marlborough. Nutrient disorders are often suspected where in fact the causes of poor vine growth result from other factors such as water logging, phylloxera, nematodes, drought and herbicide injury.

New Zealand vineyards are commonly located on fertile soils, and normally annual fertiliser requirements are not necessary. As a general rule annual fertiliser applications can be regarded as an unnecessary expense unless indicated by deficiency symptoms, soil tests or preferably, by plant analysis.

PLANT ANALYSIS

Australian and Californian studies have shown that petioles best reflect the nutritional status of grapevines. A typical sample should consist of 30 large or 50 small petioles taken at flowering from the leaf opposite the basal cluster. The petioles should also come from leaves exposed on the outside of the vine. For monitoring the nutrient status of vines later in the season, whole leaf blades (without the petioles) can be taken from mid shoot leaves during fruit ripening.

Tentative critical nutrient standards based mainly on overseas research are listed for petioles and leaf blades in Tables 35 and 36 respectively. These values are presently being evaluated for New Zealand conditions. Sprays containing Mn, Zn, or Cu can cause high levels if the sampled tissues are not washed in water. Varieties are known to differ in nitrate and Zn levels, so the standard concentrations listed in Tables 35 and 36 may not apply in all situations.

Table 35: Standard petiole concentrations for chemical analysis of grapevines at full bloom.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Total nitrogen	< 0.8	0.8 – 1.0	> 1.2
Nitrate nitrogen*	< 570	570–1750	> 1750
Phosphorus	< 0.15	0.21–0.50	> 0.5
Potassium	< 1.0	1.5 – 2.5	> 3.0
Calcium	< 1.0	1.4 – 2.5	–
Magnesium	< 0.2	0.31–0.8	> 1.0
Sulphur	< 0.15	0.21–0.5	> 0.5
Sodium	–	0.02–0.5	> 0.5
Chloride	–	0.5 – 1.5	> 2.0
Micronutrients (ppm)			
Manganese	< 20	25–200	> 200
Iron	< 30	31–100	> 100
Zinc	< 20	25–50	> 100
Copper	< 4	5–20	> 25
Boron	< 25	31–50	> 250

* Expressed as ppm

Table 36: Standard concentrations for foliar analysis of grapevines during fruit ripening.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 1.0	1.5 – 2.8	> 4.0
Phosphorus	< 0.10	0.16–0.25	> 0.4
Potassium	< 0.6	1.1 – 1.6	> 2.6
Calcium	–	2.0 – 4.0	> 4.0
Magnesium	< 0.15	0.2 – 0.5	> 0.8
Sulphur	–	0.21–0.4	> 0.5
Sodium	–	0.05–0.12	> 0.25
Chloride	–	–	> 0.5
Micronutrients (ppm)			
Manganese	< 20	41–100	> 450
Iron	< 35	40–100	> 250
Zinc	< 20	26–40	> 300
Copper	< 4	18–34	> 100
Boron	< 25	31–50	> 300

SOIL TESTING

There is a lack of definitive soil test levels for grapevines in NZ, but the following values have been found as a useful guide in Hawkes Bay and Poverty Bay. A different relationship can be expected for soils in other districts where the Mg and Ca status of soils will be much lower. The recommended MAF soil test levels are:

pH	Ca	P	K	Mg	S (SO_4)
5.8-6.8	10+	30+	15-20	20-40	10+

Boron deficiency can be expected with a soil test value of less than 0.5 ppm B, and toxicity with more than 2.5 ppm B in hot water extracts. In acid soils, Al, Mn and possibly Cu toxicities may be expected. Aluminium toxicity can be expected with a soil pH of 5.0 or less, and when the exchangeable Al is more than 50 mg/kg (N KCl extract). Manganese toxicity is expected with a soil pH of 5.0 or less, and reducible Mn levels (extracted in N ammonium acetate at pH 7) of more than 100 mg/kg. Copper toxicity is expected with a soil pH of less than 6 and more than 25 mg/kg exchangeable Cu in sandy soils, and more than 100 mg/kg in clay soils (extracted in N ammonium acetate of pH 7).

FERTILISER REQUIREMENTS

A guide to the potential quantity of fertiliser needed to maintain high fruit yields can be estimated from the nutrient removed in the harvested fruit. For example, the estimated nutrient removal in a 20 tonne/ha Mueller Thurgau crop is listed in Table 37.

Table 37: Estimated nutrient removal in a 20 tonne/ha Mueller Thurgau crop.

	kg/ha		kg/ha
Macronutrients		Micronutrients	
Nitrogen	38	Manganese	0.1
Phosphorus	8	Iron	0.2
Potassium	62	Zinc	0.04
Calcium	7	Copper	0.04
Magnesium	3	Boron	0.2

Making allowances for fertiliser inefficiency and root and shoot growth, the following inputs would be required in kg/ha: N, 66; P, 20; K, 122.

While the above calculations could lead to annual maintenance fertiliser applications, it is recommended that the grower follows the recommendation given in Table 38 and makes whatever applications are needed, only when indicated by plant analysis.

Table 38: Recommended fertiliser applications for grapevines where plant analysis indicates deficiency (see text for notes modifying these recommendations).

Element	Vine Age	Soil Types	Application Rate kg/ha
Nitrogen	Young Vines (first two years)	Silt/loam soils	0–30
		Coarse sandy or gravel soils	40–50
		Clay soils	40–50
	Mature Vines	Silt/loam soils	0–60
		Sand and gravel soils	60–100
		Clay soils	100
Phosphorus	Preplant	Auckland gumland soils	250
		Hawkes Bay/Poverty Bay alluvial soils	130
	Mature Vines		25–50
Potassium	Mature Vines		120
Magnesium	Mature Vines		50–70
Boron	Mature Vines		3

Growers are cautioned against annual applications of N as this may produce undesirable vigour problems. Commonly, NZ vineyards are excessively vigorous, and annual N applications will make this problem worse. In fact, in many situations generous N applications may be the cause of this problem. Growers are recommended to monitor nutrient levels in the vines before using N. Excessive shoot growth, particularly late in the season will reduce crop sugar levels.

The rates of N listed in Table 38 are based on studies in California where soils are commonly of lighter texture than those in NZ. It is stressed that growers should consider rates of about half the values given unless nutrient tests indicate severe deficiency levels. Where grassing down is used, an extra 20-30 kg N/ha could be applied if no clovers are present. Where the vineyard shows only limited weak areas, spot treatment rather than blanket treatment should be considered. For young vines grown on soils other than the silts and loams N should be applied using spilt applications during early spring and mid summer.

To correct severe deficiencies of K in California, rates containing up to 1000 kg K/ha have been found to be necessary. New Zealand growers are advised to use these high rates only on trial plots initially as large, single applications of potash could induce Mg and Ca deficiencies.

Applications of K can be made in late autumn or early winter to heavy soils, or early spring for light textured soils.

Where the presence of a micronutrient deficiency has been confirmed, foliar rather than soil application of fertilisers is commonly used to correct the imbalance (Table 39). To avoid possible toxicity problems arising though care should be taken when using this method of application.

Where deficiencies involving N, Mg and B are indicated, either solid or foliar fertilisers can be applied (Tables 38 and 39). Boron is normally applied as a mixed fertiliser (eg, borated superphosphate), but growers are cautioned against repeated annual dressings. Applications are required only every 2-8 years. Apply fertiliser to the soil in autumn or early winter.

A guide to liming rate is given below. A target pH range of 5.8-6.8 is recommended with a minimum of 5.5. Note that for a subsoil pH problem, surface broadcasting is not effective in overcoming the problem. Lime must be incorporated deeply and be well mixed into the soil.

To raise the pH by 0.5 units for a 20 cm layer of soil requires the following amounts of ground limestone (85% $CaCO_3$):

Sandy soils	1.75 tonne/ha
Silt loams	3.0 tonne/ha
Clay soils	5.5 tonne/ha

On acid northern gumland clays rates of lime of 7.5 to 10 tonne/ha are not uncommon and may need to be repeated to raise the pH to desirable levels.

Table 39: Recommended foliar applications for grapevines where plant analysis indicates deficiency.

Element	Frequency and Timing	Application Rate Quantity/100 l
Nitrogen*	—	500–1000 g urea
Magnesium	1–6 sprays, 10 days apart; commence soon after leaf emergence	1.5 kg Epsom salts
Manganese	(Mild deficiency) 2–6 sprays, 2 weeks apart until symptoms disappear	100 g $MnSO_4$
	(Severe deficiency) 1–4 sprays, 2 weeks apart until symptoms disappear	200 g $MnSO_4$ + 300 g hydrated lime
Iron	—	400 g $FeSO_4$
Zinc	Single spray; apply 2–3 weeks before flowering	400 g $ZnSO_4.7H_2O$ + 30 g hydrated lime
Boron	Apply prior to flowering	100 g Solubor®

* Foliar urea should not be applied during flowering

NUTRIENT DISORDERS

Deficiencies most likely to occur are N, K, Mg and B. Less common deficiencies include S, P, Mn, Zn and Fe. Deficiencies of Ca, Cu and Mo are not likely to be observed. Likely toxicities include Al and Mn on acid soils, and B on light textured soils irrigated with water containing B in excess of 1 mg/l.

Symptoms associated with N deficiency include foliage which is pale green to yellow-green. Typically, young leaves near the shoot tips are yellow and internodes are short. Yields can be greatly reduced with severe deficiency. Nitrogen deficiency is more common on light textured soils, where soil organic matter is low, or where the vineyard inter-row area is grassed down. Such grass swards can utilise up to 70 kg N/ha.

Potassium deficiency symptoms become obvious in early summer at the leaf margin and progress into the area between the main veins. Leaves are characteristically shiny. The yellow leaf areas can turn bronze or red (for coloured fruit varieties) and marginal burning and leaf curling also occurs. Alternatively K deficiency may show up as black leaf, where blue-black flecks appear in mid season on the upper leaf surface. This symptom commonly occurs on American (Labrusca) grapes. With severe deficiency, shoot growth is reduced and leaves may drop early. The lower part of the bunch stem may collapse, causing berry raisining. Potassium deficiency can be confused with leaf roll virus symptoms.

Magnesium deficiency results in chlorosis (yellowing) of margins of basal leaves in mid season. The chlorosis moves inward between primary and secondary veins, and may become creamy white in colour for white varieties. Leaf margin burn may subsequently develop. For red fruited varieties, a red interveinal colouring develops. Magnesium deficiency is commonly found on sandy soils, especially where heavy K applications have been made. It is also commonly found on vines grafted to certain phylloxera resistant rootstocks such as SO_4

Foliar symptoms of B deficiency appear in early summer. Young leaves show a mottled fading between the veins which can develop as a severe interveinal chlorosis. When severe, older leaves will show interveinal necrosis. The shoot tip commonly dies, and lateral growth develops. Tendrils and internodes near the shoot tip show black bands when held up against the light. Root extension is reduced, and the tips are swollen and stubby. Fruit set is much reduced and small seedless berries are commonly found along with normal sized ones. Boron deficiency effects on leaf deformation and fruit set can be confused with similar 'fan leaf' virus symptoms. Similarly, longitudinal cracks in the shoots can be confused between acute B deficiency and 'corky bark' virus. Boron deficiency is commonly found on sandy, gravelly soils particularly those with low pH. Temporary deficiency is often associated with drought.

As with other B sensitive plants, the margin between B sufficiency and toxicity is very narrow for grapes. Extreme care should therefore be taken when applying B fertilisers. The first sign of B toxicity is dark brown to black spots around the inside of the leaf margin which can also develop inwards towards the centre of the leaf between the veins. Young leaves typically show cupping. When severe, defoliation of all but the youngest leaves is seen. Boron toxicity can be due to irrigation water with a high B concentration or excessive application of B fertiliser. The latter has occurred on the sandy and gravelly soils in Marlborough.

Manganese toxicity is to be expected on acid soils, especially where waterlogging is a frequent occurrence. Among the most consistent symptoms of high Mn content of leaves is the development of black stripes along the conducting tissues (shoots and petioles); the leaf is rolled, marginal necrosis is common and leaf fall is frequent. Yield can be severely reduced.

There are no characteristic foliar symptoms associated with Al toxicity, although root growth is restricted and young plants may die. Both Mn toxicity and Al toxicity can be overcome by raising the soil pH above 6.0.

Methods and rates suitable for correcting specific nutrient deficiencies in grapevines are outlined in Tables 38 and 39.

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PIP FRUIT

Apples (*Malus domestica*) and European pears (*Pyrus communis*) are grown throughout NZ under a wide range of climatic conditions and soil types. Recently, another pip fruit, the Asian or Japanese pear (*Pyrus pyrifolia*) has been introduced and is being tried over a similar range of conditions.

Large differences in soil fertility occur in the soils on which pip fruit are planted and this has a considerable influence in their response to, and requirement for applied fertilisers. Many Hawkes Bay orchards for example are on deep fertile alluvial soils which are well supplied with nutrients. These soils are able to maintain continual heavy cropping with little or no applied fertilisers. Orchards on low fertility clay soils in other areas though are very responsive to fertiliser and lime and often require heavy applications for high production, or at least until fertility levels have been built up.

In recent years there has been a considerable expansion of pip fruit onto soils which have not been widely used in the past. Consequently, careful monitoring of the nutrient status of soil and plants will be necessary while satisfactory fertiliser programmes are being developed for these soils. For example, new orchards on light sandy soils in Hawkes Bay may require heavy fertiliser applications for satisfactory orchard performance compared with the traditional orchard soils used in this area.

The growth and fruiting habits of apples, European pears and Asian pears (nashi) are similar in many respects so for practical purposes it is reasonable to assume that their nutrient requirements will not differ markedly. Where there are specific differences these will be indicated in the following sections.

PLANT ANALYSIS

Leaf samples for chemical analysis should be collected from the current season's extension growth during January-February. Approximately 40-80 youngest mature leaves should be sampled at random from the non-fruiting laterals on trees throughout the orchard.

As foliar nutrient concentrations can be influenced by rootstock and varietal differences, it is important that separate samples be collected from individual cultivars and that the leaves for each cultivar come from scions on common rootstocks. Suggested concentration standards, based on surveys in Australian pip fruit orchards, are listed in Table 40.

SOIL TESTING

Pip fruit should be grown within a pH range of 5.8-6.8 and it is important that liming occurs on a regular basis to ensure this. While apples and nashi will grow satisfactorily at values lower than 5.8, a topsoil (0-40 cm) pH of around 6.5 is desirable for control of Ca disorders which affect fruit. These include bitter pit in apples, and Ishinashi and Yuzuhada in nashi; hard flesh disorders that affect the surface appearance and texture of fruit, especially the cultivars Nijisseiki and Shinseiki.

Acceptable MAF soil test levels for Ca and P are > 10 and > 30, respectively. To maintain a balance between the major cations it is suggested that soil test values for Ca, K and Mg be in the ratio of 1.6-2:1:2.

Table 40: Standard concentrations for foliar analysis of pip fruit*.

Element	Crop	Deficient	Normal	Excess
Macronutrients (%)				
Nitrogen	Apple	< 1.6	1.9 –2.4	> 3.0
	Pear	< 1.8	2.3 –2.7	> 3.5
Phosphorus	Pip fruit	< 0.09	0.14–0.20	> 0.30
Potassium	Apple	< 0.7	1.1 –1.5	> 2.0
	Pear	< 0.7	1.2 –2.0	> 2.0
Calcium	Apple	< 0.7	1.0 –2.0	> 2.5
	Pear	< 0.8	1.5 –2.1	> 3.7
Magnesium	Apple	< 0.15	0.25–0.35	> 0.45
	Pear	< 0.13	0.30–0.50	> 0.90
Sulphur	Apple	–	0.20–0.40	–
	Pear	< 0.10	0.17–0.26	–
Sodium	Pip fruit	–	0.02	> 0.50
Chloride	Apple	–	0.3	> 1.0
	Pear	–	0.1	> 0.5
Micronutrients (ppm)				
Manganese	Apple	< 25	50–160	> 200
	Pear	< 25	60–120	> 200
Iron	Apple	< 60	100–250	> 500
	Pear	–	60–200	–
Zinc	Pip fruit	< 10	20–50	> 80
Copper	Apple	< 3	5–20	> 100
	Pear	< 5	9–20	> 50
Boron	Apple	< 15	20–50	> 80
	Pear	< 10	20–40	–

* Data from Leece (1976)

Where laboratories supply cation exchange capacity measurements (CEC) it is recommended that Ca, K and Mg should respectively constitute approximately 70-80%, 3-4% and 10-15% of the exchange complex. Due to the nature of the CEC measurement and the mineralogy of the clay fraction in NZ soils there are major difficulties associated with achieving so called optimum ratios based on this measurement. It should be realised that in most NZ soils CEC is pH dependent. In many laboratories CEC is routinely measured at pH 7 with the result that the reported values are a considerable overestimation of the CEC at field pH. As a consequence of this the percent saturation of each of the elements (Ca, Mg, K) will be artificially low, implying that additional fertiliser is required if strict adherence to the optimum ratios is being followed. Fertiliser recommendations based on such measurements may in fact be unnecessary.

Soil cation ratios for pip fruit, or other crops, have not been calibrated against growth or yield for any soil/crop system in NZ. It is clear that many crops tolerate quite wide variations in these ratios hence an alternative approach is to apply the fertiliser required for adequate growth and crop removal and monitor the nutritional status with leaf analysis.

Soil sampling is best carried out in autumn or early winter. In orchards where fertiliser is broadcast, samples (0-20 cm) should be taken at random under the drip zone. In cases where fertiliser has been banded, the samples should only be taken in areas under the drip zone which have previously received fertiliser. Occasional samples at depths of 20-40 and 40-60 cm are useful to check pH.

FERTILISER REQUIREMENTS

Nitrogen use in pip fruit orchards should be based on the inherent fertility status of the soil. On deep fertile alluvial soils N need not be applied unless low foliar N concentrations, poor fruit set-biennial bearing problems or pale fruit problems in green varieties occur. On soils of average fertility annual rates as high as 300 kg N/ha have been advocated although 80-120 kg N/ha should be sufficient in most circumstances. On soils of low fertility application rates should be based on 25 kg N/ha/10 tonne of anticipated crop reducing to 10-15 kg N/ha/10 tonne of crop once plateau yields have been reached.

Rates for P and K, (Table 41) are based on the soil fertility status. Use of potash needs to be approached with caution. Excessive applications of K tend to depress Ca and Mg uptake and increase the incidence of Ca related disorders in fruit and Mg deficiency.

In developing a K fertiliser programme it is necessary to take into account soil reserves as well as the expected crop load. Soils that fix K or those with nil or very low reserves will require higher rates than soils which contain clay minerals able to easily replenish K removed through crop uptake. Soils that fix K usually have very low soil test K levels even although apparently adequate amounts of K are being applied. Application rates of 400-800 kg K/ha will be required on these soils to prevent K deficiency. As an example of the use of Table 41 assume that a soil with high K reserves returns MAF soil test levels of K; 7 and Ca; 24. Compared with Ca, the K value is less than half the Ca value (0.5 × 24 = 12). If a 30 tonne/ha crop was anticipated, the annual K requirements can be estimated as being 36-45 kg K/ha (3 × 12-15 kg K/ha/10 tonne of crop). No such calculation is required to establish the P requirements. Rather, the application rate is determined directly from the table depending on the P status of the soil as determined by MAF soil test.

In orchards with wide herbicide strips (> 2 m) fertiliser and lime applications should be directed towards the herbicide strip in preference to the grass alleyway which has fewer feeder roots. Where orchards have narrow herbicide strips, or where these are absent, fertilisers can be banded between the drip zone and the trunk. Alternatively, all fertilisers can be broadcast.

Older orchards have traditionally been clean cultivated and during this period have lost considerable amounts of topsoil and applied nutrients through erosion. More recently, grassing down with a herbicide strip along the tree row has become the predominant soil management system. Halting these losses, and the contribution of substantial amounts of N from clover in grassed down swards has altered the fertility status in such orchards. This needs to be recognised and fertiliser inputs adjusted accordingly to match the gradual increase in fertility.

Table 41: Suggested maintenance fertiliser rates for established pip fruit and nutrient removal in a 10 tonne/ha crop.

Element	MAF Soil Test Level	Application Rate	Crop Removal kg/ha
Nitrogen	—	(kg N/ha) 80–100	6–11
Phosphorus		(kg P/ha)	0.7–1.4
	> 70	–	
	30–70	50	
	10–30	100	
	< 10	250	
Potassium	Soils with low K reserves*	(kg K/ha/10 tonne crop)	10–15
	a) K < 0.5 × Ca	20–30	
	b) K > 0.6 × Ca	7–20	
	c) K intermediate between a) and b)	15–20	
	Soils with high K reserves*		
	a) K < 0.5 × Ca	12–15	
	b) K > 0.6 × Ca	–	
	c) K intermediate between a) and b)	7–10	
Calcium	—	—	0.3–0.7

* Recent soils and those from greywacke and schist have high K reserves; peats and strongly weathered and leached soils with granitic or volcanic parent materials have low K reserves.

NUTRIENT DISORDERS

There are no peculiarities that set the visual symptoms of nutrient disorders in pip fruit apart from those of other crops (see Introductory Section for symptoms of nutrient deficiencies). The most common disorders affecting pip fruit production in NZ are the deficiencies of N, Mg, Ca, Mn, Zn and B.

Good N status over the blossom/fruit set period is essential and shortages at this stage of development can lead to poor fruit set and accentuate biennial bearing. With some varieties, the threshold for fruit set may be higher than that required for vegetative growth. Pears and certain green apple varieties such as Granny Smith appear to have higher N requirements than red or partially coloured varieties. With these latter varieties, high N levels tend to reduce fruit colour so N fertiliser needs to be used with caution and only sufficient applied to maintain regular fruit set.

Magnesium deficiency (Mg < 0.12%) has been particularly prominent in young nashi orchards outside of the Hawkes Bay-Poverty Bay region. With this disorder patches of necrotic tissue gradually develop in the interveinal tissue of older leaves from mid summer onwards. Soil applications of Kieserite at 500 kg/ha, or Epsom salts ($MgSO_4$) or Causmag at rates of 200 kg Mg/ha are suitable long term corrective measures. Successive foliar applications of 1-2 kg $MgSO_4$/100 l are beneficial for alleviation of deficiency symptoms on a season by season basis.

Zinc deficiency (Zn < 10 ppm) is occasionally seen in parts of Central Otago and Canterbury and may be corrected with sprays of zinc sulphate (1-2 kg/100 l) during dormancy or regular sprays of Zineb® in the fungicide programme. Zinc chelates are also suitable for foliar application.

Manganese deficiency is occasionally seen, but in pip fruit Mn toxicity symptoms are more common. These occur on very acid soils, or heavy clay soils with poor drainage and may be overcome by correction of drainage and pH problems. Where deficiency occurs it can be overcome by lowering the soil pH through use of acidifying fertilisers, or with early season sprays of manganese sulphate plus lime at concentrations of 600 g $MnSO_4$ plus 800 g hydrated lime/100 l.

Boron is the only common trace element deficiency occurring in pip fruit orchards in NZ. Boron deficiency is usually associated with the development of internal cork tissue similar to bitter pit. It can be distinguished from the latter disorder (which results from the presence of inadequate Ca in the fruit) in that the cork tissue tends to extend right into the core zone. Sometimes external fruit distortion is present and this may be associated with fruit russet or cracking. Symptoms of deficiency while evident in the fruit, may be absent on the foliage. Twig dieback symptoms and visual symptoms on foliage may be observed where new pip fruit orchards have been established on soils containing very low levels of B. Nashi cultivars such as Nijisseiki and Shinseiki are susceptible to B deficiency, corky spots developing in the flesh at the calyx end of the fruit. These taste bitter and are undetectable from the exterior of the fruit. With pears the predominant symptom is blossom blast in which the blossoms may wilt, die, or fail to burst. The symptoms occur randomly, rarely affecting more than 10-20% of the trees in an orchard and are usually confined to 1-2 leaders per tree.

On soils with an established history of B deficiency (eg, in the Nelson region) annual dressings of borax (10 kg/ha) are necessary. Early season sprays of boric acid (100 g/100 l) or borax (200 g/100 l) are alternatives to soil application.

Attempts to increase B levels in nashi fruit by foliar applications of borated compounds have proved unsuccessful in Japan although it is not known if early season sprays were tried. Japanese recommendations for correction of B deficiency in nashi orchards (B < 13-18 ppm in mature leaves) are for addition of B to soil only. Soluble B in the soil, as determined by hot water extraction, should be above 0.3 ppm B. Deficiency symptoms are associated with soluble B levels of less than 0.2 ppm B.

Like B, deficiencies involving Ca are manifest in fruit without the appearance of visual symptoms on foliage. Good subsoil Ca levels are thought to reduce the incidence of bitter pit. Hence on acid , low Ca soils, deep incorporation of lime pre-planting followed by regular lime applications of at least 2.5 tonne/ha every 2-3 years are suggested. Potash inputs should also be reduced if bitter pit occurs through over fertilisation with K.

With most apple varieties, foliar sprays of calcium nitrate (600 g/100) or calcium chloride (400 g/100) can be used as an additional means of elevating fruit Ca levels. A minimum of six sprays should be applied at regular intervals during the period from early December through to harvest to be effective. Chemical analysis of fruit can be used to predict the liklihood of bitter pit occurring. Standards for optimum Ca concentrations in particular cultivars are not widely available however, and it is not usual for growers to request this type of analysis.

Similar strategies need to be adopted to control 'hard flesh' Ca disorders in nashi. Ussurian pea pear rootstock (*P. betulaefolia*) is recommended where Ca deficiency is likely to occur in poorly drained orchards. Removal of young extension shoots in November-December, and thinning of flowers and immature fruit are also practices advocated by the Japanese to control Ca deficiency in fruit. There have been indications from NZ work that where Ca sprays at concentrations suitable for bitter pit control have been applied to Hosui and Kosui, significant foliar damage has resulted. The Japanese recommend that foliar applications of calcium chloride are suitable for application to Asian pears. At the present time however the timing and concentration of these sprays is not known.

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STONE FRUIT

In NZ the full range of stone fruits (*Prunus* spp.) may be grown. Apricots (*P. armeniaca*), sweet cherries (*P. avium*) and European plums (*P. domestica*) have fairly high winter chilling requirements and prefer dry climates so are confined to the drier eastern and southern districts from Hawkes Bay to Central Otago. Peaches (*P. persica*), Japanese plums (*P. salicina*), and to a lesser extent nectarines (*P. nucipersica*), are more adaptable and are grown throughout the country.

The soil types used for stone fruits range from the deep fertile alluvial soils of Hawkes Bay, which require little fertiliser, to very light sandy shallow soils of low fertility which can be highly responsive to fertiliser. Because stone fruits are very intolerant of poor drainage they are rarely planted on soils prone to waterlogging such as heavy clays.

As with pip fruits there has been recent expansion of the stone fruit industry onto soil types which have not been widely used for orchards in the past. With little history and experience of stone fruit nutrition on these soils, it will be necessary to carefully monitor the nutrient status of these crops until satisfactory fertiliser programmes can be developed.

The nutrient requirements of the major stone fruit crops are not sufficiently different to warrent separate discussion of each. Where there are specific requirements or susceptibilities to nutrient disorders, these will be outlined in the following sections.

PLANT ANALYSIS

The standard sampling procedure consists of collecting approximately 50 of the youngest mature leaves (including petioles) from the current season's extension growth during the January-February period. Separate leaf samples should be collected for individual cultivars where more than one type is being grown within the orchard. Suggested concentration standards, based on Australian surveys, are listed in Table 42.

Table 43: Standard concentrations for foliar analysis of stone fruit*.

Element	Crop†	Deficient	Optimum	Excess
Macronutrients (%)				
Nitrogen	Apricot, plum	< 1.7	2.4 -3.0	> 4.0
	Cherry	< 1.7	2.2 -2.6	> 3.4
	Peach	< 2.4	3.0 -3.5	> 4.0
Phosphorus	Stone fruit	< 0.09	0.14-0.25	> 0.40
Potassium	Apricot	< 1.0	2.0 -3.5	> 4.0
	Cherry, plum	< 1.0	1.6 -3.0	> 4.0
	Peach	< 1.0	2.0 -3.0	> 4.0
Calcium	Apricot	< 1.0	2.0 -4.0	> 4.5
	Cherry	< 0.8	1.4 -2.4	> 3.5
	Peach	< 1.0	1.8 -2.7	> 3.5
	Plum	< 1.0	1.5 -3.0	> 4.0
Magnesium	Stone fruit	< 0.20	0.30-0.80	> 1.10
Sulphur	Stone fruit	–	0.20-0.40	–
Sodium	Stone fruit	–	0.02	> 0.50
Chloride	Stone fruit	–	0.3	> 1.0
Micronutrients (ppm)				
Manganese	Stone fruit	< 20	40-160	> 400
Iron	Stone fruit	< 60	100-250	> 500
Zinc	Stone fruit	< 15	20-50	> 70
Copper	Apricot, cherry, peach	< 3	5-16	30
	Plum	< 4	6-16	30
Boron	Apricot, cherry peach	< 15	20-60	> 80
	Plum	< 20	25-60	> 80

* Data from Leece (1976)
† Peach values can be used for nectarines.

SOIL TESTING

In high producing stone fruit orchards the soil pH should be maintained around 6.0-6.7 in the top 40 cm of soil. At low subsoil pH, root growth and tree health are adversely affected by Al and Mn toxicity, hence preplant soil testing and deep placement of lime are recommended to adjust pH prior to orchard establishment.

Target soil test levels and soil sampling methods for stone fruit are similar to those given in the corresponding section for pip fruit.

FERTILISER REQUIREMENTS

The quantity of N fertiliser required is dependent on the depth and fertility characteristics of the orchard soil, and its management in regard to cultivation and weed control. The N rate reported for optimum orchard performance where soils have been found responsive to N fertiliser range from 100-150 kg N/ha although responses have been obtained with annual rates as high as 250 kg N/ha. The former amounts are probably suitable for our conditions, providing growth, cropping and fruit quality remain satisfactory.

Where vigour is excessive, and fruit colour poor the amount of fertiliser should be reduced, or on very deep fertile soils even eliminated. On the other hand where tree growth is poor, foliage pale, and soils known to be of low fertility, increases in rate beyond 150 kg N/ha could be considered providing other causes of poor tree performance have already been eliminated.

Young trees require much less N than mature, cropping trees. As their root system is initially close to the tree trunk it is important that fertilisers are spread within reach of their roots. Care must be taken, however, not to place any quantity of concentrated fertiliser around the base of the trunk in order to avoid risk of fertiliser burn. A good guide is to apply fertilisers evenly to the area covered by the drip zone. Suitable rates for young trees planted at 5 × 2 m spacings in a high density stone fruit orchard on soils of average and low N status are listed in Table 43.

Table 43: Suggested application rates (g N/tree) for N in young, high density (5 × 2 m spacings) stone fruit orchards on soils of average and low N fertility.

Age (year)	Application Rate: Average Fertility Soils	Low Fertility Soils
1	25	37.5
2	50	75
3	75	112.5
4	100	150

Normal practice in NZ has been to apply 1/2-2/3 of the N in early spring before growth commences and the remainder late spring-early summer around November-December. Where water sprinkling is used for frost protection, particularly on very light soils, spring N applications are best delayed until after the main frost fighting period has passed in order to minimise losses by leaching. On very light soils with low natural N supply several smaller dressings may be preferable to a single dressing, particularly if total N rates for the season are in excess of 150 kg N/ha. Neutral forms of N such as calcium ammonium nitrate should be used in preference to strongly acidic forms such as diammonium phosphate, ammonium sulphate or urea. This is particularly important where the application is being banded rather than broadcast as localised areas of very low pH are difficult to correct by liming. Acidic forms are preferred however where soil pH is high as these assist in the correction of pH-induced trace metal deficiencies by lowering soil pH to more reasonable levels.

Annual fertiliser requirements for N, P and K are listed in Table 44. As with pip fruit, the potash requirement is dependent on the K status and reserves in soil. When the reserve K status of the soil has been identified the amount of K necessary can be determined from the soil test values of K and Ca and the size of crop anticipated. For example, on a soil with low K reserves returning MAF soil test levels of K; 17 and Ca; 30, K is intermediate between 0.5 × 30 (15) and 0.6 × 30 (18). If a 40 tonne/ha crop was anticipated annual K requirements are 80 kg K/ha (4 × 20 kg K/ha/10 tonne of crop).

Stone fruit trees have low P requirements and positive responses to P fertiliser are rare. There are numerous examples however of stone fruit orchard performance being adversely affected by excess applications of P fertiliser. Consequently, the soil P status and levels of application considered suitable for satisfactory yields of stone fruit (Table 44) are lower than those considered normal for other orchard crops.

Methods of application, either broadcasting or banding, are the same as those described for pip fruit. Fertigation, using ammonium nitrate as the N source has been shown to lead to poor peach tree performance after several years use. This is thought to be due to adverse effects of low soil pH within the root zone from the acidifying action of the ammonium nitrate. Presumably, use of other acid types of fertiliser such as urea in trickle irrigation would have similar adverse effects. For this reason fertigation of stone fruits must be approached with extreme caution and will require properly balanced nutrient solutions to avoid adverse effects such as root damage from low pH.

NUTRIENT DISORDERS

Where they are present, stone fruit tend to display classical visual symptoms of macro and micronutrient disorders (see Introductory Section for symptoms of nutrient deficiencies). Trace element deficiencies, with the exception of B, are generally more common in NZ grown stone fruit than pip fruit. Their occurrence is usually associated with over-liming, or with soils which have naturally high pH. These latter conditions are most likely to occur in Central Otago, Hawkes Bay and Poverty Bay, but can be seen occasionally in other districts, particularly on sites of old Maori shell middens or lime dumps.

pH-induced Mn deficiency (Mn < 20 ppm) is the most common of the trace element disorders. This can be controlled on a seasonal basis by foliar sprays applied early during the growing season (600 g $MnSO_4$ plus 800 g hydrated lime/100 l). Permanent correction of the disorder may be attempted by soil application of acidifying compounds such

Table 44: Suggested annual maintenance fertiliser requirements for stone fruit and nutrient removal in a 10 tonne/ha crop of peaches†.

Element	Soil Factor	Application Rate	Crop Removal kg/ha
Nitrogen	Soil Fertility	(kg N/ha)	23
	High	–	
	Average	50–100	
	Low	100–150	
Phosphorus	MAF Soil Test Level	(kg P/ha)	2
	> 30	–	
	10–30	20–30	
	< 10	100	
Potassium	Soil K Reserves and K and Ca Soil Test Level	(kg K/ha/10 tonne crop)	19
	Reserves low*		
	a) K < 0.5 × Ca	30–40	
	b) K > 0.6 × Ca	10	
	c) K intermediate	20	
	Reserves high*		
	a) K < 0.5 × Ca	20	
	b) K > 0.6 × Ca	–	
	c) K intermediate a) and b)	10	

† Mature peach and nectarine orchards should yield around 20–30 tonne/ha on average, however modern high density orchards should be able to attain regular yields in excess of 40 tonne/ha for higher yielding mid to late season varieties. Apricot yields are around half, cherries a quarter and plums about two thirds the yield of peaches.

* K reserves in different soil types are given in Table 41.

as ammonium sulphate, urea, finely ground S or aluminium sulphate to lower pH.

Zinc deficiency ($Zn < 15$ ppm) is common in Central Otago. With the exception of cherries which do not respond readily to foliar Zn sprays, Zn deficiency in stone fruit can be controlled by early season foliar sprays (400 g $ZnSO_4$ plus 400 g hydrated lime/100 l).

Iron deficiency ($Fe < 60$ ppm) is less common than either of the above two disorders and little is known about specific control measures under local conditions. Where the deficiency has been induced through overliming, the best approach is to lower the pH with acidifying agents, as outlined for Mn deficiency. Soil applications of iron chelate (50-100 kg/ha) in spring have proved successful overseas.

For most stone fruit varieties, fruit symptoms are usually the first sign of B deficiency and are more common than dieback or other foliage disorders. In apricots, fruit show severe external cracking, internal cork, particularly around the stone cavity, and a tendency to prematurely ripen in the centre. Cherries exhibit pale chlorotic skins which may crack and develop grey spots within the fruit. Brown sunken areas and occasional gum pockets appear in the flesh of B deficient plums while peach fruit tend to be small and abnormal with internal necrotic patches. Where stone fruit are planted on soils of marginal B status apricots are the crop most likely to exhibit deficiency symptoms. Peaches and plums are relatively less sensitive to low B levels and better able to sustain normal fruit growth under such conditions.

Boron deficiency is best controlled by annual foliar sprays of boric acid (100 g/100 l) or borax (200 g/100 l) applied in the spring. Because of the narrow safety margin between B deficiency and B toxicity, soil applications of borated fertilisers are not recommended for stone fruit.

Peaches and nectarines are very sensitive to B toxicity. This can arise in new plantings on soils previously used for apples where borated fertiliser was routinely applied. Boron toxicity caused by high soil levels is difficult to overcome. The most practical solution is to grow a more tolerant crop, such as apples, rather than trying to reduce the B level by leaching or alleviating the toxicity effects by liming or addition of organic matter.

Apricots and plums are more tolerant of excess B. In addition, these plants have the ability to translocate excess B from the leaves to the fruit and the bark so that excessive concentrations seldom appear in the leaves. Consequently, marginally yellowed or burned leaves are not characteristic of B toxicity symptoms in these two crops and symptoms may be confused with those of B deficiency. In this instance leaf analysis is particularly useful to assist in providing a reliable diagnosis. Typical symptoms of B toxicity include thickening of the leaves, corkiness along the midribs and petioles, enlarged nodes, bark necrosis and death of the shoot tips.

FURTHER READING

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(G.I. Langford, D.T. Jordan, P.E. Smale)

BLACKCURRANTS

There has been considerable work on blackcurrants (*Ribes nigrum*) by British and East European scientists. Few NZ results are available although trials have recently been established at Templeton.

PLANT ANALYSIS

Samples for leaf analysis should be collected 2-3 weeks before fruit maturity. The youngest mature leaves on new season's growth should be selected and the leaf, plus the petiole, taken for chemical analysis. Each sample should consist of about 50 leaves taken at random from 10 or more bushes. Interpretive standards for nutrient concentrations are listed in Table 45.

Table 45: Standard concentrations for foliar analysis of blackcurrants.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 2.6	2.9 –3.0	> 3.0
Phosphorus	< 0.25	0.26–0.30	> 0.30
Potassium	< 1.0	1.5 –2.0	> 2.0
Calcium	< 1.0	2.0	–
Magnesium	< 0.1	0.15–0.6	> 0.6
Micronutrients (ppm)			
Manganese		30–100	
Iron		50–100	
Zinc		20–40	
Copper		5–10	
Boron		20–40	

FERTILISER REQUIREMENTS

It is clear from the results of overseas trials, and from monitoring blocks within NZ, that the fertiliser requirements of blackcurrants are not well understood. Annual NPK recommendations for example vary between 40-140 kg N/ha, 0-120 kg K/ha and 0-50 kg P/ha. The following recommendations are guidelines only and have been based on crop removal factors (Table 46) with allowances for leaching, pruning removal and new growth.

Table 46: Nutrient removal in a 10 tonne/ha crop of blackcurrants.

Element	Crop Removal kg/ha
Nitrogen	20
Phosphorus	5
Potassium	44
Calcium	8
Magnesium	3
Sulphur	4

To minimise leaching losses and to coincide with periods of maximum crop demand it is suggested that the N requirement (5 kg N/tonne of fruit anticipated/ha) is split; half being applied immediately prior to growth commencement in spring, with a second application before fruit swelling in early December.

Soil tests (taken in May) are suggested as the basis for determining K and P requirements. Potash should be applied at rates of 5 kg K/tonne of fruit anticipated/ha and 3 kg K/tonne/ha where MAF soil test levels are between 5-10, and 11-20, respectively. Additional K will be required for test levels below 5. Phosphorus at a rate of 1 kg P/tonne/ha is recommended for soil test levels of between 5-15. Soil reserves are sufficient to meet crop requirements where test levels for K and P respectively exceed 20 and 15.

While there is insufficient information to suggest that more than one application is necessary, potash could be applied with N in spring and early December as a split dressing. As with other soft berries, blackcurrants are sensitive to excess chloride, hence sources of K other than muriate of potash (KCl) need to be used for quantities in excess of 100 kg K/ha.

The Ca and Mg requirements of blackcurrants are small, consequently, regular dressings of these elements are not normally applied. When foliar analysis or soil tests indicate the need, 15-20 kg Mg/ha should suffice. Blackcurrants perform better at pH levels above 5.8. Use of lime or dolomite every 2-3 years to maintain pH will ensure that the Ca and/or Mg requirements of this crop are adequately met.

NUTRIENT DISORDERS

While responses in growth and subsequent yield to various fertiliser treatments have been recorded, foliar symptoms attributable to nutrient deficiencies have rarely been observed in NZ. Nitrogen deficiency (N < 2.6%) where the leaves develop bright orange, red or purplish red colourings, or potassium deficiency (K < 1.0%), where leaves that first show reddish-purple tints gradually develop a necrotic marginal scorch, are likely to be the most common disorders encountered.

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BLUEBERRIES

Blueberries are distinguished from other crops in that they thrive on acid peats or sandy mineral soils where the pH is between 4-5. There are several reasons for this requirement. The efficiency with which blueberries take up Fe is low. Consequently, acid conditions are required to increase the quantity of Fe available in soil solution. In addition, acid conditions also ensure that N is able to exist in the form of ammonium (NH_4^+) which is more readily utilised by blueberries than other N sources, such as nitrate (NO_3^-).

This review concentrates on highbush *Vaccinium corymbosum* species which are currently the most widely grown commercially.

PLANT ANALYSIS

Samples for leaf analysis should be collected in the three week period immediately prior to harvest, and subsequently, during the first week of harvest. The youngest mature leaves on fruiting shoots should be selected, with each sample consisting of about 50 leaves taken at random from 10 or more bushes. Large plantings should be divided into about 2 ha units with one or two samples being taken from each area. Interpretive standards for nutrient concentrations are listed in Table 47.

SOIL TESTING

The most important information to be obtained from soil testing is pH which should lie between 4-5. Suggested MAF soil test levels for the macronutrients are P, 15-25; K, 6-10; Mg, 10-12; and Ca < 8.

FERTILISER REQUIREMENTS

Maintenance fertiliser applications are listed in Table 48. These rates should be adjusted to meet local requirements, eg, soils with volcanic ash components may require higher P rates to compensate for P fixation.

The need for N applications should be based on the concentration of N in the leaves and the type of soil. Peat soils require a single N application in spring only (September 15 - October 15). These rates (30-40 kg N/ha) should also be applied to mineral soils. However, to ensure that N is available throughout growth on mineral soils where N is more likely to be leached, a further 20 kg N/ha, either as a single or split application, should be applied in summer (early December). Ammonium sulphate, diammonium phosphate or urea should be used for N applications rather than fertilisers which supply N in the form of nitrate.

Table 47: Standard concentrations for foliar analysis of blueberries*.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 1.70	1.80–2.10	> 2.50
Phosphorus	< 0.10	0.12–0.40	> 0.80
Potasium	< 0.30	0.35–0.65	> 0.95
Calcium	< 0.13	0.40–0.80	> 1.00
Magnesium	< 0.08	0.12–0.25	> 0.45
Sulphur	< 0.10	0.13–0.25	–
Chloride	–	–	> 0.50
Micronutrients (ppm)			
Manganese	< 23	50–350	> 450
Iron	< 60	60–200	> 400
Zinc	< 8	8–30	> 80
Copper	< 5	5–20	> 100
Boron	< 20	30–70	> 200

* After Doughty, Adams, and Martin (1981).

Foliar N applications are not recommended overseas.

Of the other nutrients, potassium sulphate is preferred to muriate of potash (KCl) to prevent possible plant injury from chloride.

NUTRIENT DISORDERS

The most common nutrient disorders affecting production are those associated with N and Fe. Nitrogen deficiency (N < 1.7%) is associated with reduced vigour and cessation of growth before the end of the season. Unlike other crops, the colouration of the entire leaf gradually changes to red as the deficiency advances. Young shoots (whips) arising from the base of N deficient plants have a distinct pink colour. These turn pale green however when growth ceases. In severe instances of deficiency, defoliation of the older

Table 48: Suggested annual fertiliser application for established blueberries on peat and mineral soils and estimated nutrient loss in a 10 tonne/ha crop.

Element	Application Rate: Peat Soils kg/ha	Application Rate: Mineral Soils kg/ha	Crop Removal kg/ha
Nitrogen	30–40	50–60	11.2
Phosphorus	10	10–20	1.3
Potassium	20–30	20–30	8.1
Calcium	10–20	–	1.5
Magnesium	10–20	10–20	–
Sulphur	<50	–	–
Manganese	10–20	–	–
Iron	–	–	0.1

leaves may occur, while those that remain may have necrotic spots on part of, or over the entire leaf surface. Death of the growing tip also occurs. Flower number, fruit set, fruit size, and yield are all reduced by N deficiency.

Iron deficiency (Fe < 60 ppm) is likely to be induced by high pH which makes Fe less available. Young leaves at the shoot tip exhibit an interveinal chlorosis with a fine lace like network of green veins. The internodes are not shortened, nor is the leaf size or shape markedly affected as is the case with Zn deficiency which also affects these leaves. The symptoms of Fe deficiency may be confused with those of Mn deficiency; however, the two can be differentiated in that leaves with Mn deficiency tend to have a broader band of green tissue either side of the major veins. Small basal leaves and yellow shoots are symptomatic of severe Fe deficiencies.

Other nutrient deficiencies are less likely to occur, although instances of B (B 20 ppm) and Zn deficiency (Zn 8 ppm) have been observed in NZ. Shoot tip leaves of B deficient plants are usually small, bluish-green in colour and distorted in appearance. Chlorotic spotting of young leaves is likely and auxilary buds turn brown. Shoot die back is quite prominent.

Correction of Fe deficiency can be achieved either by reducing the pH of the soil with acidifying compounds such as elemental S, ammonium sulphate, and aluminium sulphate, or by addition of iron-containing compounds if the total Fe content in soil is inadequate in the correct pH range. Rates of 38 and 126 kg S/ha are required for 0.1 pH unit decreases on sandy and loamy soils respectively, where the pH exceeds 4.5. Aluminium sulphate, which reacts more rapidly than S, is required at six times the respective rates recommended for S.

Where the pH is less than 4, agricultural lime or dolomite can be used to bring the pH into the correct range. If it is necessary to provide Ca without appreciably altering the pH, up to 1.25 tonne/ha of agricultural lime or dolomite can be used on peat soils. For soils with pH above 5 however, gypsum or Ca-containing fertilisers such as superphosphate should be used. Autumn application of these materials is best to allow activation before the following season.

Methods and rates suitable for correcting specific nutrient deficiencies in blueberries are outlined in Table 49. To avoid possible toxicity problems arising from foliar application of trace metals care should be taken when recommending this method of correction.

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Table 49: Rate, form and method of application of nutrients for correcting specific deficiency disorders in blueberries.

Element	Soil Application Rate kg/ha	Foliar Application Rate
Phosphorus	50	–
Potassium	90	–
Magnesium +	50–60	2 kg $MgSO_4$/100 l
Iron	2–8	70 g $FeSO_4$/100 l
Manganese*	16	600 g $MnSO_4$ + 800 g hydrated lime/100 l
Boron	0.4–1	2–5 kg Solubor® /ha in 40–100 l
Zinc	2–6	14–43 kg Zn chelate/ha in 300–1000 l

\+ Use of kieserite should be avoided for foliar applications.
* Post-harvest foliar applications of Mn are recommended to avoid deposition of black spray products on fruit.

BOYSENBERRIES, YOUNGBERRIES AND BLACKBERRIES

Although the bramble group (*Rubus* hybrids) constitutes a significant proportion of the national berryfruit area, surprisingly little is known about their nutritional requirements. Virtually no controlled work has been carried out in NZ on either application, responses, or leaf tissue analysis for brambles and the overseas literature in this area is frequently inconsistent.

PLANT ANALYSIS

Samples for leaf analysis should be collected from primocanes during January and February. Each sample should contain approximately 50 youngest mature leaves (including petiole) selected at random from 10 or more canes. There is little published information on chemical analysis of leaf tissue for these crops. The data presented for boysenberries (Table 50) is based on a compilation of results recorded at Ruakura over a number of years, hence is only an indication of the sorts of concentrations anticipated.

Table 50: Typical concentrations for foliar analysis of boysenberries.

Element	Range
Macronutrients (%)	
Nitrogen	2.8 3.7
Phosphorus	0.17–0.34
Potassium	1.39–1 89
Calcium	0.65–1 37
Magnesium	0.22–0.46
Sulphur	0.18–0.32
Micronutrients (ppm)	
Manganese	134–304
Zinc	28–60
Copper	8–29
Boron	38–57

Values for youngberries are not considered to differ markedly from those of boysenberries.

FERTILISER REQUIREMENTS

To date fertiliser applications in NZ have been made to ensure adequacy, rather than based on crop data or plant needs. No nutrient removal figures are available for this group, and fertiliser recommendations from various sources are widely divergent. NPK rates for example range between 28-160 kg N/ha, 35-112 kg P/ha and 28-160 kg K/ha. Despite the variation, these rates are still considerably less than those many NZ growers are presently applying. Boysenberries in California and Oregon have shown little yield response to the level or timing of fertiliser applications. This suggests NZ growers could, with careful monitoring, reduce the rates being used here.

Table 51: Suggested annual fertiliser application for established bramble crops.

Element	MAF Soil Test	Application Rate kg/ha
Nitrogen	–	75–100
Potassium	13–20	0
	7–12	70
	0–6	180
Phosphorus	26–45	0
	16–25	20
	9–15	50
Magnesium	21–35	0
	11–20	30
	0–10	60

For this group of crops applications of N should be based on plant vigour, soil type and rainfall, with P, K, and Mg application based on soil test levels (Table 51). A pH range of 5.8 - 6.5 is considered satisfactory. Where Ca, or pH levels are below those suggested, lime should be applied in autumn or early winter. If this is coupled with low Mg levels, lime and magnesium oxide (which is less expensive), or dolomite should be used.

On young plants banding of fertiliser on both sides of the row is accepted practice, however, by the third year this is usually broadcast.

Applications of N throughout the growing season are advantageous, but there appears to be no disadvantages in applying P and K in single applications in either autumn or spring. As the plants continue growing well into the autumn, post-harvest applications of water and nutrients should continue into this period.

Proprietory mixes suitable for berryfruit are available in most regions. Experience with chloride based fertilisers in the Nelson region has shown no deleterious effects on boysenberries, but this should be watched particularly in areas without irrigation or very low summer rainfall. Blackberries, which are amongst the least tolerant of the berry crops to excess chloride, should receive sulphate based potash fertiliser until experience suggests otherwise.

FURTHER READING

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GOOSEBERRIES

The large fruited varieties of gooseberry now being cultivated are derived from the English or European gooseberry. Very little is written about the nutrition of gooseberries (*Ribes uva-crispa*) and recommendations are often made based on those for blackcurrants.

PLANT ANALYSIS

Limited data is available for this crop. Leaf analyses should be standardised as the youngest mature leaves from current season's growth. Petioles should be included, and samples collected during the January/February period.

FERTILISER REQUIREMENTS

In line with recommendations for blackcurrants the following rates of fertiliser are suggested as being suitable for NZ conditions, the actual quantities to be applied being determined from the crop load anticipated and the nutrient status of the soil as measured by MAF soil test (Table 52).

Table 52: Annual fertiliser applications for gooseberries.

Element	MAF Soil Test	Application Rate* kg/ha
Nitrogen	–	50
Phosphorus	>15	–
	5–15	10
Potassium	>20	–
	11–20	30
	5–10	50

* The values assume a crop load of 10 tonne/ha. To determine the quantity of fertiliser required for other crop loads, these figures should be scaled up or down according to the anticipated yield.

A pH range of 6.0-6.5 is considered desirable for gooseberries.

NUTRIENT DISORDERS

Gooseberries have a high K requirement. Leaves with K deficiency (K < 0.90%) become bluish green with purple tints prior to the appearance of a marginal scorch or necrosis.

Despite warnings that only sulphate forms should be used on berryfruits, no damage has resulted in the UK where compound fertilisers based on potassium chloride have been used. It is recommended however that preplant soil applications be in the sulphate form.

FURTHER READING

Gardiner, R. (1977). *Bush Fruits.* Bulletin 4, Ministry of Agriculture, Fisheries and Food, HMSO, London, pp. 103.

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RASPBERRIES

Raspberries (*Rubus idaeus*) are the most important of the berryfruits in the *Rubus* genus produced commerically overseas. Consequently, most of the nutritional studies and fertiliser experiments have been conducted with this species. Despite the amount of research done on raspberries however, it is still not possible to provide definitive nutritional information on how the crop should be grown under our own conditions.

PLANT ANALYSIS

Samples for leaf analysis should be collected from primocanes during the December/January period. Approximately 50 youngest mature leaves (plus petioles) should be selected from 10 or more bushes to obtain a representative sample for plant analysis. Typical nutrient concentrations expected for this crop are listed in Table 53.

FERTILISER REQUIREMENTS

Rates of fertiliser suitable for established raspberries are presented in Table 54. The quantity of P, K and Mg required depends on the nutrient status of the soil. Consequently, reference should be made to a MAF soil test when determining the rate to be applied. Fertiliser may be applied in bands 15-30 cm either side of the row to young plants, or broadcast once the crop is established. As for related *Rubus* species, a pH range of 5.8-6.5 is considered desirable.

There is general agreement that multiple applications of fertiliser through the season are beneficial. Jenner and Parminter (1981) suggest August and November applications at approximately 2/3:1/3. Others suggest that P and K should be applied in autumn or spring. Side dressings of

Table 53: Standard concentrations for foliar analysis of red raspberries (Washington State University Data).

Element	Below Optimum	Optimum	Excess
Macronutrients (%)			
Nitrogen	2.5	2.75	>4.0
Phosphorus	0.2	0.3	>0.6
Potassium	1.0	1.5	>3.0
Calcium	0.5	0.6–2.5	>2.5
Magnesium	0.25	0.4	>1.0
Micronutrients (ppm)			
Manganese	20	80	>300
Iron	30	50	>150
Zinc	13	34	>80
Copper	1	2	>50
Boron	30	46	>80

Table 54: Annual fertiliser applications for established raspberries and nutrient removal in a 10 tonne/ha crop.

Element	MAF Soil Test	Application Rate kg/ha	Crop Removal* kg/ha
Nitrogen	–	75–100	57
Phosphorus	> 45	0	8
	26–45	10	
	16–25	20	
	0–15	50	
Potassium	> 20	0	52
	13–20	75	
	6–12	100	
	0–6	200	
Magnesium	> 20	0	8
	11–20	30	
	0–10	60	

* Based on data of Wood *et al.* (1962).

N in early summer are advantageous to ensure a constant N supply throughout growth. Multiple applications of N are not recommended however for autumn cropping raspberries in the Waikato where a single application of 100 kg urea/ha in September appears to be sufficient. Applications of fertiliser later in the season encourage growth of excessively tall canes which are difficult to harvest.

The rates in Table 54 are lower than those advocated by Jenner and Parminter (1981). It appears however that raspberries can reach optimum quality and yields on quite modest fertiliser applications. As fertiliser costs are becoming a significant proportion of total production costs, more consideration should be given to relating the amounts of fertiliser required to crop yield thereby avoiding over fertilisation. With careful monitoring of performance, a gradual reduction in applications should be possible.

Several compound high analysis fertilisers suitable for raspberries are available in NZ. Those based on chloride should be avoided. Other manufacturers supply mixes suited to berryfruit, often formulated from MAF recommendations.

NUTRIENT DISORDERS

Providing a complete fertiliser programme is followed, it is unlikely that macronutrient deficiencies will occur. Work on the nutrition of Red Antwerp raspberries in the Nelson region during the early 50's showed that increased vigour and yield responses could be obtained following addition of micronutrient fertilisers containing Cu, Zn or Mo. Plants showed few, if any symptoms of deficiency however. Of all the micronutrient disorders though, B deficiency is probably the most important.

The typical symptom of B deficiency appears as a dieback with delayed budbreak, or complete budbreak failure (Askew *et al.*, 1951). Some buds give rise to distorted leaves with unusually large petioles and a border of necrotic tissue. Leaves forming later do not show this. Less severely affected buds give rise to leaves with small deeply indented leaflets which persist throughout the season. Symptoms are rarely seen on the primocanes.

Concentrations of B in affected leaves of the Red Antwerp variety grown in the Nelson region ranged between 13-25 ppm. Responses to B and leaf concentrations associated with deficiency symptoms in other varieties may be different.

If specific deficiencies involving Mn, B or Cu have been identified, and confirmed by leaf analysis, correction with the following treatments should be sufficient to alleviate the disorders. For Mn deficiency 1-4 foliar applications containing 200 g $MnSO_4$ plus 300 g hydrated lime/100 l should be applied at intervals approximately 10 days apart until symptoms disappear. Black oxide spray deposits may occur on foliage and fruit with this treatment however. If it is necessary to continue the applications when fruit is present, spray concentrations of 100 g $MnSO_4$/100 l will avoid the problem. Soil applications of 9-36 kg borax/ha, or foliar applications of 5-20 kg Solubor® dissolved in water and applied at a rate of 100-400 l/ha, are recommended for correction of B deficiency in raspberries. Copper deficiency can be treated with foliar applications of copper oxychloride (1 kg/100 l) applied at a rate of 200-300 l/ha. A wetting agent should be used if it is not already included in the product.

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Table 55: Standard concentrations for foliar analysis of strawberries.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 2.0	2.6 –3.5	–
Phosphorus	< 0.20	0.25–0.35	–
Potassium	< 1.0	1.0 –2.0	–
Calcium	< 0.5	0.7 –1.5	–
Magnesium	< 0.10	0.25–0.40	–
Sulphur	< 0.10	0.15–0.35	–
Sodium	< 0.01	0.02–0.10	> 0.10
Chloride	–	–	> 0.50
Micronutrients (ppm)			
Manganese	< 20.0	200–500	–
Iron	–	100–200	–
Zinc	< 15	30–80	–
Copper	–	5–12	–
Boron	< 20	30–100	> 250

STRAWBERRIES

General fertiliser recommendations for strawberries (*Fragaria* spp.) are difficult to make because the cropping character varies markedly between regions. Past recommendations have been based on the belief that strawberries require large amounts of fertilisers. Repeated cropping on an annual replant system, which is commonly practised in northern North Island regions, will require higher annual applications than longer plant retention systems. Fertiliser recommendations stated in this review are for production under annual replant cropping. For longer plant retention fruit nutrient removal estimations should be used to guide recommendations.

PLANT ANALYSIS

Generally, foliar nutrient analyses are better for assessing nutritional status than soil tests. Ideally, both should be used.

American nutrient monitoring has indicated that substantial nutrient accumulation occurs during fruiting. If a nutrient is limiting it is more likely to be detected during this period. Also, prior to this in a recently transplanted plant, most of the nutrients come from stored reserves within the crown and root system. Consequently, sampling should be done during fruiting, preferably at first harvest.

Approximately 50 youngest mature leaves should be selected at random throughout the area and separated from their petioles. Large plantings are best divided into halves or quarters and a sample taken from each area. Nutrient concentrations compiled from American surveys and limited local information are listed in Table 55.

SOIL TESTING

Strawberries grow well in soils with a pH range between 5.3-6.5. A pH around 6.5 is best with sandy textured soils whereas for finer textured soils a pH closer to 5.3 is preferable.

Suitable MAF soil test levels for this crop are P, 30-40; K, 15-25; Mg, 30-40; and Ca, 10-20.

FERTILISER REQUIREMENTS

Suggested maintenance fertiliser applications for annual replant strawberries are listed in Table 56. The rate for each element needs to be assessed separately depending on the previous soil use, whether or not the soil is of volcanic origin or whether nutrient disorders were evident in the previous season. Areas out of pasture, for example, may have adequate N fertility and require little or no applied N during the first season. Volcanic soils which have high allophanic clay contents (Yellow-brown loams), on the other hand, will require larger amounts of P than other mineral soils where the ability to interact chemically with added phosphate is much less.

Most fertiliser sources are suitable for application to strawberries with the exception of muriate of potash (KCl) and composite high analysis fertilisers containing chloride. Because of the sensitivity of this crop to chloride, irrigation

Table 56: Maintenance fertiliser programme for annual replant strawberries and estimated nutrient removal in a 30 tonne/ha crop.

Element	Soil Parameters	Application Rate kg/ha	Crop Removal kg/ha	
			Fruit	Plant
Nitrogen	Ex pasture	0–25	30	27
	Replant	50–100		
Phosphorus	Replant; low P retentive soil	20–30	5.5	4.0
	Replant; high P retentive soil (volcanic ash)	50–60		
	Low P in soil, or P deficiency	μ 80		
Potassium	Replant	80–100	40	23
	Low K in soil or k deficiency	μ 150		
Magnesium	Replant	20–30	3.0	5.0
	Low Mg in soil, Mg deficiency	50–70		
Calcium	Ca deficiency	100	5	27

water and fertiliser containing this element should be avoided. As a result of this, potassium should be used in the sulphate form.

Fertigation

With the increased use of under-mulch irrigation, the use of fertiliser application via the irrigation water (fertigation) will become more common to supplement a small basal fertiliser dressing. This is an efficient practise which can lower the fertiliser cost and improve crop performance. Fertigation enables dissolved fertiliser to be placed in the active root zone which is otherwise difficult to do because of the polythene mulch.

Generally, the fertiliser application rate can be halved if fertigation is used. However, until experience is gained, this technique should be adopted with caution and regular tissue analyses done to monitor nutrient levels. Also, soil tests before planting and after plant removal will indicate how soil nutrient levels have been influenced by fertigation.

NUTRIENT DISORDERS

The most likely disorders encountered in strawberry production are deficiencies involving K, P, Mg and N.

The first symptoms of K deficiency ($K < 1.0\%$) appear on the upper leaf margins of the older leaves. The serration tips redden, the injury gradually progressing inwards between the veins until most of the leaf blade is affected. This is accompanied almost simultaneously by a symptom which appears to be unique to strawberries. The rachis (extension of the petiole to the central leaflet) darkens and dehydrates. The blade area either side of this tissue is similarly affected. Few runners are producted on K deficient plants. Those that are tend to be short and thin with few plants. Fruit are insipid, colourless, and pulpy.

Phosphorus deficiency ($P < 0.1\%$) can be recognised by the dark green colour and black metallic-like sheen on the upper surface of leaves. The lower leaf surfaces may develop a reddish-purple tint which becomes evident on the upper surface of some varieties as the leaves become older.

Symptoms of Mg deficiency ($Mg < 0.1\%$) are similar to those for other crop species; tissue in the interveinal regions of older leaves which has an initial chlorosis eventually becomes necrotic as the deficiency progresses. In some instances, a marginal scorch forming a halo pattern can be observed near the base of the serrations on the older leaves.

Plants with mild N deficiency ($N < 2.0\%$) have small chlorotic older leaves. More severe deficiencies cause shortening of the petioles which turn red and become brittle. Frequently, as the leaves and fruit calyxes age, they also become reddish, the leaves particularly so.

The symptoms of these and other nutrient disorders in strawberries are well described and illustrated in a publication by Ulrich *et al.* (1980). In addition they also outline corrective measures to alleviate trace metal disorders which are less likely to arise in normal cropping situations. Fertiliser rates suitable for correcting the macronutrient disorders outlined above appear in Table 56.

FURTHER READING

Albregts, E.E. and Howard, C.M. (1980). Accumulation of nutrients by strawberry plants and fruit grown in annual hill culture. *Journal of the American Society of Horticultural Science, 105:* 386-388.

Boyce, B.R. and Matlock, D.L. (1966). Strawberry nutrition. In: *Temperate to Tropical Fruit Nutrition.* (Childers, N.F., Ed), Horticultural Publications, Rutgers — The State University, USA, pp. 518-548.

Johanson, F.D. (1981). Nutrient deficiencies in strawberries. In: *The Strawberry — Cultivars to Marketing.* (Childers, N.F., Ed), Horticultural Publications, New Jersey, USA, pp. 514.

Ulrich, A., Mostafa, M.A.E. and Allen, W.W. (1980). *Strawberry Deficiency Symptoms: A Visual and Plant Analysis Guide to Fertilisation.* University of California, USA, pp. 58.

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GREENHOUSE CUT FLOWERS

The nutritional requirements of greenhouse floriculture crops depend largely on the medium in which they are grown, and whether liquid fertilisers or solid fertilisers are used. Requirements are also likely to vary according to the season or stage of growth of the plant. The fertiliser recommendations given in this bulletin are based on average growing conditions and as such are likely to vary according to local conditions. It is therefore important that the crop is monitored closely with soil and plant analysis.

PLANT ANALYSIS

Leaf samples for analysis for the various plant species should be collected in the following way:

Carnations —	Youngest mature leaves (fifth and sixth leaf pair from top of lateral — 60 leaves per sample).
Chrysanthemums —	Youngest mature leaves (20-30 leaves per sample).
Cymbidium orchids —	Youngest mature leaves (fifth and sixth leaf cut at base — 15-20 leaves per sample).
Roses —	Youngest mature leaves on flowering stem — 20-30 leaves per sample.
Gerberas —	Youngest mature leaves (20-30 leaves per sample)

Standard leaf concentrations for assessing the nutrient status of the various plant species are listed in Tables 57 and 58.

SOIL TESTING

Because of the diverse nature of the media in which the plants are grown it is difficult to give generalised target soil test values which would be suitable for every situation. However, the following values listed in Tables 59 and 60 have been found to be suitable under commercial conditions.

If soil test levels are below those suggested additional quantities of nutrient will need to be applied. Generalised recommendations concerning the sorts of increases to MAF soil test values that can be obtained following incorporation of fertiliser into the top 15 cm of soil are outlined in Table 61.

Table 57: Typical concentration ranges for foliar analysis of greenhouse grown roses and gerberas.

Element	Roses	Gerberas
Macronutrients (%)		
Nitrogen	3.0 -4.0	2.1 -3.2
Phosphorus	0.25-0.35	0.25-0.42
Potassium	2.0 -3.0	2.5 -4.3
Calcium	1.0 -1.6	0.8 -1.6
Magnesium	0.25-0.35	0.25-0.80
Sulphur	0.25-0.50	–
Sodium	0.01-0.05	–
Micronutrients (ppm)		
Manganese	70-120	25-230
Iron	80-120	50-230
Zinc	20-40	40-75
Copper	7-15	5-11
Boron	40-60	30-45

Rates of limestone required to increase the pH of soils of differing texture are listed in Table 75. Where it is necessary to decrease pH acidifying compounds such as finely ground elemental S (13 kg/100 m^2) or aluminium sulphate (32 kg/100 m^2) will reduce the pH by up to 1 unit. The pH ultimately achieved however is very dependent on soil type.

FERTILISER REQUIREMENTS

The quantities of fertiliser required will depend on the medium in which the plants are grown. The procedure for mineral soils is to calculate the quantity of fertiliser needed from the information given in Table 61 to achieve the desired target soil test values (Table 59). Once these soil values have been achieved, fertility can be maintained by applying liquid fertiliser (Table 62), or dry side dressings.

Liquid fertiliser programme for carnations

Liquid fertiliser applications (Table 62) should commence as soon as the plants are established (4-6 weeks after planting of cuttings). Towards the end of winter it is often beneficial to reduce the feeding rate as N accumulated in the soil becomes more readily available as the soil warms up. A sudden excess of N increases the tendency for calyx splitting. Stock solutions prepared during this period should contain 0.5 kg urea and 0.66 kg KNO_3/10 l, rather than the quantities listed (Table 62).

Boron deficiency is sometimes encountered when the pH and Ca content of the soil is high. In such cases 20 g of borax (dissolved in hot water) per 10 l of stock solution should be included. On dilution this will give a concentration of 1 ppm B. Concentrations of 0.5-2 ppm B in nutrient solutions are considered to be satisfactory for carnations, however, growers using B should monitor the concentration in leaves to ensure that they are not applying excessive amounts and running the risk of causing B toxicity.

Table 58: Standard concentrations for foliar analysis of greenhouse grown carnations, chrysanthemums and cymbidium orchids.

Element	Carnations			Chrysanthemums			Cymbidium Orchids		
	Deficient	Optimum	Excess	Deficient	Optimum	Excess	Deficient	Optimum	Excess
Macronutrients (%)									
Nitrogen	< 2.5	3.5 –4.2	> 5.0	< 3.0	4.5 –5.5	> 6.2	< 1.0	1.4 –2.1	> 2.6
Phosphorus	< 0.12	0.25–0.4	> 0.5	< 0.2	0.4 –0.6	> 0.9	< 0.1	0.15–0.24	> 0.32
Potassium	< 1.8	2.8 –4.0	> 5.0	< 3.0	4.5 –6.5	> 7.0	< 0.8	1.3 –2.5	> 3.3
Calcium	< 0.6	1.0 –1.6	> 2.2	< 0.3	0.8 –1.8	> 2.5	< 0.3	0.4 –1.5	> 2.0
Magnesium	< 0.2	0.3 –0.4	> 0.5	< 0.2	0.25–0.6	> 0.8	< 0.08	0.12–0.22	> 0.25
Sulphur	< 0.2	0.27–0.35	0.45	< 0.22	0.3 –0.5	> 0.6	< 0.08	0.12–0.27	> 0.35
Sodium	–	0.1 –0.5		–	0.1 –0.2	–	–	0.0 –0.4	> 0.5
Micronutrients (ppm)									
Manganese	< 19	50–250	> 400	< 20	100–300	> 400	< 15	41–300	> 400
Iron	< 40	50–120	–	< 60	100–400	> 500	< 20	41–120	> 180
Zinc	< 15	20–60	> 100	< 15	30–80	> 200	< 14	18–22	> 55
Copper	< 2	6–10	> 30	< 5	10–25	> 50	< 2	4–15	> 30
Boron	< 20	30–100	> 200	< 20	30–80	> 150	< 10	21–120	> 260

Table 59: Target MAF soil test values for greenhouse cut flower crops grown in mineral soils.

Plant	pH	N*		P	K	Ca	Mg	Soluble Salts (%)	
		Early Season	Mid Season					Early Season	Mid Season
Carnations	6–6.5	50–100	40–60	80–100	25–30	12–18	35–60	0.15	0.10
Chrysanthemums	6–6.5	50–100	40–60	80–100	30–40	12–18	35–50	0.15	0.10
Roses	6–6.5	50–100	40–60	50–70	25–35	12–18	35–60	0.15	0.10
Field grown nursery stock	6–6.5	+	+	30–50†	15–25	12–18	35–50	0.15	0.10

* Results expressed as ppm mineral N (μ g/g soil)
\+ Apply 50–150 kg N/ha preplanting. For slow growing plants apply a topdressing of 50 g/g N/ha.
† For Leucadendron Safari Sunset or Red Gem and Telopea, values greater than 60 may be too high. Desirable values are 20–50; even lower values may be preferable for soils with low P retention.

Table 60: Desirable nutrient values for soil-less media such as peat or bark using 1:1.5 water extraction. Results expressed as ppm in the extract.

Plant	pH	NO_3-N	P*	K	Mg	Ca	Conductivity (mS)
Carnations	5.3–6.5	50–100	20–55	150–300	20–80	50–120	2.0–3.0
Cymbidium Orchids	5.5–6.0	43–56	10–15	40–58	29–37	–	1.8

* Desirable P values in bark should be: Carnations 10–30
Cymbidiums 6–10

Table 61: Increases to MAF soil test values following incorporation of 1 kg of nutrient per 100 m^2 to a depth of 15 cm†.

Element		Unit Increase
N		50–60*
P	Low P retention soils	15–20
	High P retention soils	10–12
K		2.5–3.5
Mg		10–14
pH	(see text)	

† 1 kg/100 m^2 is equivalent to 100 kg/ha
* Units for N are ppm

Liquid fertiliser programme for roses

In addition to the standard formulation (Table 62) Mg should occasionally be added to the stock solution at a rate of 500 g Epsom salts/10 l. Iron chelate should also be applied three to four times a year (500 g chelated iron (6% Fe)/10 l).

Liquid fertiliser programme for orchids

For post flowering and young plants the higher rate of N (Table 62) is required where non-nitrogen composted pine bark is used. Iron should also be applied once every two months at 0.5-1 ppm Fe (5-10 g chelated iron/1000 l).

For flowering plants the N input (Table 62) should be halved over the summer months (1-2 months after flowering has finished) to enhance spike formation. There are reports of beneficial effects of B on flower development at 0.05 ppm (4.5 g borax/1000 l) during the summer. In addition high K (150 ppm K) during the period of flower development may increase the shelf life of the blooms.

Table 62: Liquid fertiliser stock solutions for greenhouse flowers.

Plant	Fertiliser	Stock Solution kg/10 l	Dilute Solution* N ppm	K ppm
Carnations	Potassium nitrate	0.8	193	152
	Urea **or**	0.6		
	Ammonium nitrate	(0.8)		
Chrysanthemums	Potassium nitrate	0.8	135	152
	Urea **or**	0.375		
	Ammonium nitrate	(0.5)		
Roses	Potassium nitrate	1.05	200	200
	Urea **or**	0.54		
	Ammonium nitrate	(0.73)		
Orchids				
a) Post Flowering and Young Plants	Potassium nitrate	0.52–0.78	150–170	100–150
	Ammonium nitrate	0.55		
	Monoammonium phosphate	0.30		
	Epsom salts	0.50		
b) Flowering Plants	Potassium nitrate	0.78	75	150
	Monoammonium phosphate	0.30		
	Epsom salts	0.50		
General Cut Flowers				
a) Winter	Potassium nitrate	1.05	200	200
	Ammonium nitrate	0.73		
b) Summer	Potassium nitrate	0.80	193	152
	Ammonium nitrate	0.80		

* N and K concentrations resulting from a 1:200 dilution of the stock solution

Base fertiliser mix for use in peat and bark modules

The quantity of macronutrient in these modules (long plastic bags of peat or bark laid horizontally on the glasshouse floor) is generally low. Solid fertilisers are mixed into the media before filling the modules. These fertilisers provide the suitable acidity (pH) in the media, an initial buffer of nutrients, and supply nutrients which are not easily added by liquid fertilisers. All macro and micronutrients should be supplied in a base fertiliser (Table 63). This is essential as peat and bark, unlike soil, contain only small amounts of plant nutrients.

Table 63: Base fertiliser mix for use in peat and bark modules†.

Fertiliser	Quantity
Macronutrients (kg/m^3)	
Dolomite	4*
Calcium nitrate	0.47
Potassium nitrate	1.27
Magphos + Kinsealy trace elements	4
Micronutrients (g/m^3)	
Borax	13.8
Zinc sulphate	16.8
Sodium molybdate	2.8
or fritted trace elements eg. FTE36	(500)

* Use 10 kg/m^3 for peat modules

† Add 100 l/m^3 while mixing the fertiliser into the peat or bark. The media will be very hard to wet later if water is not added during mixing.

Once the base fertility has been brought up to the desired value (Table 60) the liquid fertiliser programme described above for mineral soils can be used.

NUTRIENT DISORDERS

The symptoms of nutrient disorders of greenhouse flower crops are similar to those of other horticultural crops (see Introductory Section for symptoms of nutrient deficiencies). Several disorders though have specific symptoms which are quite distinctive when expressed in particular crops.

Nitrogen deficiency of carnations is known as curly tip. The tips of leaf pairs tend to hook together so that subsequent leaves do not have adequate growing room and as a result become folded as they develop. This deficiency also results in the formation of narrow, stiff leaves in carnations which is referred to as grassiness. In chrysanthemums, pink or reddish-brown spots, sometimes affecting entire older leaves, may appear in some cultivars. Flower colour is deeper or paler than normal, the expression of the deficiency again being dependent on the cultivar. The weight and number of flowers, and stem thickness are all reduced by N deficiency in roses.

Potassium deficiency is localised on the older leaves which are frequently mottled and usually have necrotic patches of tissue near the tip and margins. At early stages of the deficiency a marginal chlorosis occurs, the chlorosis subsequently appearing in the interveinal tissue also. The margins eventually become brown and permanently curled prior to defoliation. This progression is quite common in chrysanthemums, for example, where the initial marginal chlorosis first appears as spots 1-2 mm in diameter. In carnations, necrotic spots are scattered over the entire leaf surface. These spots gradually enlarge, coalesce and eventually destroy the leaf centre.

Potassium deficiency affects rose production by reducing the number of first grade flowers produced. Stems weigh less and are shorter than normal. Bent neck symptoms are observed on cut roses with this deficiency. Flowers fail to open normally and after a few days the stem bends over immediately below the bud. This symptom is not specific to K deficiency however; other factors may be responsible.

Where excessive amounts of K have been used the colour intensity of flowers may be reduced.

FURTHER READING

Amos, J. (1980). Flowers and Ornamentals. Liquid feeding: basic requirements and formulations. New Zealand Ministry of Agriculture and Fisheries Aglink, HPP 171.

Burge, G.K., White, R.A.J. and Prasad, M. (1983). Soilless Mixtures. Peat or bark modules for greenhouse tomatoes and other crops. New Zealand Ministry of Agriculture and Fisheries Aglink, HPP 245.

Crossley, M. (1984). Cymbidium Orchids. Growing media and nutrition requirements. New Zealand Ministry of Agriculture and Fisheries Aglink, HPP 306.

GREENHOUSE PEPINOS

Pepino (*Solanum muricatum*) is a herbaceous perennial of the Solonaceae family, originating in the Northern Andes region of South America. Protected cultivation is considered desirable to improve yields and fruit quality as well as allowing all year round production.

PLANT ANALYSIS

Leaf samples should be taken from shoots in good light and consist of the youngest mature leaf. Regular sampling of foliage for tissue analysis will aid in programming nutrient supply, particularly N. A sample could be taken every month from 2-3 weeks after planting.

Values from a survey of growers suggest the following tentative concentrations: N, 3%; P, 0.3%; K, 3-4%; Ca, 3%; Mg, 0.5-1.0%.

The use of high inputs of K to hold vegetative growth and restrict the effect of N does not appear to be effective. A desirable N concentration in the leaves is less than 3% DM. Concentrations above this are excessive and must be reduced by withholding N fertiliser applications and perhaps a defoliation programme. Because N is remobilised from older to younger foliage, removing older leaves will reduce the N status of the plant.

The requirement for P and K seems to be moderate. Target soil test values for P should be 40-50 units and K, 15 units. These values should be achieved at planting time, after any base fertiliser has been applied. Target soil test values for Mg should be 30-40 units at planting. A soil pH of 5.5-6.5 should be maintained.

FERTILISER REQUIREMENTS

A survey of growers has suggested a close relationship between N status of the plant and fruit quality. High N concentrations (>3%) in the leaves were associated with poorer quality fruit. Pepino is able to take up large quantities of N from the soil and for this reason N supply must be carefully controlled if fruit quality is to be maintained. No N fertiliser should be applied before planting and may not be needed for 1-2 months afterwards. Nitrogen additions should only begin when the supply is known to be depleted by observations of growth, or preferably, when diagnosed by plant analysis.

A standard liquid fertiliser such as 100 N:200 K can be used. This can be prepared from 1050 g potassium nitrate plus 140 g urea dissolved in 10 l of stock solution and diluted 1:200. Magnesium can also be added to the nutrient solution, as Epsom salts, at the rate of 1 kg/10 l of stock solution. Nutrient solution should not be applied daily, but once or twice weekly, with water only being applied in between applications.

GREENHOUSE VEGETABLES

The nutritional requirements of greenhouse grown vegetables, like cut flowers, depend largely on the medium in which they are grown. Requirements are also likely to vary according to the season or stage of growth of the plant. The fertiliser recommendations given in this bulletin are based on average growing conditions and as such are likely to vary according to local conditions. It is therefore important that the crop is monitored closely with soil and plant analysis.

PLANT ANALYSIS

Leaf samples for analysis for the following vegetables should be collected as outlined below:

Cucumber — Recently matured leaves (blade plus petiole); such leaves are located 30-45 cm from growing tip (20 leaves per sample).

Lettuce — Recently matured leaves (20-30 wrapper leaves per sample taken before head formation).

Tomato — Recently matured whole leaves (blades plus petioles); these are located about 20 cm from shoot tip (20 leaves per sample).

The sampling procedure for cucumbers is also applicable to beans, courgettes and melons. Standard leaf concentrations for assessing the nutrient status of these vegetables are listed in Table 64.

SOIL TESTING

Greenhouse vegetables are grown on a wide range of mineral and organic soils in NZ. In many cases the original soil is modified by the addition of materials such as peat, pumice or animal manures. The target values in Tables 65 and 66 have been found to be satisfactory under commercial conditions.

FERTILISER REQUIREMENTS

The procedure for mineral soils is to calculate the quantity of fertiliser or lime needed from the information given in Tables 61 and 75 to achieve the desired target soil test values (Table 65). Once these soil values have been achieved, fertility can be maintained by applying liquid fertilisers or dry side dressings.

Liquid fertiliser programmes for tomatoes

There are different recommendations for making up the stock solutions and for rates of addition. This is mostly based on tradition and is not related to soil type. The fertiliser programmes available vary from a constant concentration all season to that requiring changes in nutrient concentration and composition.

The following recommendations (Table 67) are those most widely used in NZ and suit most growing practices.

The various nutrient formulations are used to allow for the different requirements of crops depending on season, planting time and stage of growth.

For instance, a tomato crop planted in the autumn months grows into the winter with shorter days and cooler temperatures. The low light levels tend to draw plants out and at the same time reducing the quality of the fruit. In order to control this type of growth the concentration and formulation of the solution is changed. As light conditions improve, the strength of the solution is reduced, ie, is made more dilute, to allow growth to continue and fruit to swell and ripen evenly. During summer the demand for N increases so solutions higher in N replace those containing higher K levels.

It is important to make the changes gradually to avoid extreme fluctuations in growth and fruit quality.

Dry side dressing of greenhouse vegetables

Use a proprietory granulated fertiliser high in N and K. Rates of application will vary depending on their chemical analysis. A product containing 12:5:14 NPK would be applied at 5 kg/100 m² every three or four weeks. Alternatively, a mixture of 2 kg of ammonium sulphate and 1 kg of potassium sulphate per 100 m² can be used.

Base fertiliser mix for use in peat and bark modules

Because the quantity of nutrient in peat and bark is low all macro and micronutrients should be supplied. A typical fertiliser mix is listed in Table 63.

The base fertiliser recommendations (Table 63) only supply a fraction of the nutrients required by a tomato crop. The addition of a liquid fertiliser in every watering is recommended, starting immediately after planting. Initially the solution should supply 200 ppm N and 350 ppm K. Typical stock solutions for preparing liquid fertilisers for tomatoes in peat or bark modules are listed in Table 68.

Results show that the P nutrition of tomatoes in modules is inadequate at about the time the first fruits ripen, unless P is included in the liquid fertiliser. Nutrient solutions supplying P are recommended from first ripening until mid October (Table 68). After this time P can be omitted and the K concentration reduced.

Magnesium, S, Fe and B deficiencies are likely to occur in module-grown tomato crops. Magnesium sulphate should be included in nutrient solutions for two weeks in every three months as a precaution against the development of Mg and S deficiencies, or added whenever deficiency symptoms ap-

Table 64: Typical concentrations for foliar analysis of greenhouse grown vegetables.

Element	Cucumber Range	Lettuce Range	Melons Range	Tomato Deficient	Tomato Optimum	Tomato Excess
Macronutrients (%)						
Nitrogen	5.0–6.0	3.5 –4.5	4.0–5.0	< 3.0	4.0 –5.0	> 6.0
Phosphorus	0.7–1.0	0.4 –0.6	0.4–0.6	< 0.19	0.4 –0.6	–
Potassium	4.5–5.5	4.5 –6.0	4.0–5.0	< 3.0	4.0 –5.0	> 6.0
Calcium	2.0–4.0	1.0 –1.7	2.0–4.0	< 0.9	1.5 –2.5	–
Magnesium	0.5–1.0	0.14–0.27	0.4–0.6	< 0.2	0.4 –0.6	–
Sulphur	–	0.25–0.5	–	< 0.19	0.5 –1.5	–
Sodium	–	0.02–0.2	–	–	0.04–0.1	–
Micronutrients (ppm)						
Manganese	60–150	40–150	75–150	< 20	100–400	>800
Iron	100–150	100–200	100	–	80–200	–
Zinc	40–80	25–40	25–80	< 14	30–90	–
Copper	8–20	5–15	6–10	–	12–50	–
Boron	35–60	30–50	30–70	< 20	30–60	>100

pear. Do not add Epsom salts to solutions containing P as solid precipitates can result.

Iron chelate should be used in solutions for one week at 10 ppm if Fe deficiency occurs. This deficiency often occurs during dull, winter weather and recovery can be assisted by careful watering and keeping the media slightly drier for a few days.

Symptoms of B deficiency are unlikely to be obvious, but borax should be added in the nutrient solution for two weeks in mid winter and again in spring for March-May planted crops, or only in spring for June-August planted crops. Regular analysis of the media and also of the leaves of the plants should be carried out at least once a month so that the supply of nutrients can be adjusted to that taken up by the crop.

FURTHER READING

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Burge, G.K., White, R.A.J. and Prasad, M. (1983). Soil-less Mixtures. Peat or bark modules for greenhouse tomatoes and other crops. New Zealand Ministry of Agriculture and Fisheries AgLink, HPP 245.

Table 65: Target MAF soil test values for greenhouse vegetables grown in mineral soils.

Plant	pH	N*		P	K	Ca	Mg	Soluble Salts (%)	
		Early Season	Mid Season					Early Season	Mid Season
Capsicum	6.0–6.5	–	–	80–100	40–50	12–18	35–50	0.20	0.15
Courgettes	6.0–6.5	–	–	80–100	25–35	12–18	35–50	0.10	0.10
Cucumber	6.0–6.5	60–120	50–70	80–100	30–40	12–18	35–50	0.15	0.10
Lettuce	6.0–6.5	40–80	40–60	80–100	25–35	12–18	35–50	0.15	0.10
Melons	6.0–6.5	–	–	80–100	30–40	12–18	35–50	0.10	0.10
Tomato	5.5–6.5	50–100	40–60	70–100	45–60	12–18	35–50	0.20	0.15

* Results expressed as ppm mineral N (μ g/g soil).

Table 66: Desirable nutrient levels for soil-less media such as peat or bark using 1:1.5 water extraction. Results expressed as ppm in the extract.

Plant	pH	NO_3-N	P*	K	Mg	Ca	Conductivity (mS)
Cucumber	5.0–6.0	60–80	18–20	100–150	–	–	1.3–2.0
Tomato							
Initial	5.3–6.5	60–80	30–50	280–400	25–35	140–200	2.0–2.5
During Crop	5.3–6.5	30–50	20–30	140–200	25–35	140–200	1.0–2.0

* Desirable P values in bark should be: Cucumbers 8–10
Tomatoes, initial growth 15–25
Tomatoes, during crop 10–15

Table 67: Liquid fertiliser stock solutions for greenhouse tomatoes grown in mineral soils.

Nutrient Solution	Fertiliser	Stock Solution kg/10	Dilute Solution* N ppm	K ppm
1	Potassium nitrate	1.5	104	285
2	Potassium nitrate	1.5	173	285
	Urea **or**	0.3		
	Ammonium nitrate	(0.4)		
3	Potassium nitrate	1.5	242	285
	Urea **or**	0.6		
	Ammonium nitrate	(0.8)		
4	Potassium nitrate	1.5	380	285
	Urea **or**	1.2		
	Ammonium nitrate	(1.6)		
5	Urea **or**	1.5	345	–
	Ammonium nitrate	(2.0)		

* N and K concentrations resulting from a 1:200 dilution of the stock solution.

Note 1: Epsom salts at 0.5 kg/10 l of stock solution should be added to all solutions containing potassium nitrate.

Note 2: Ammonium nitrate is often used instead of urea during winter to minimise the risk of ammonia toxicity in cold soils.

Table 68: Liquid fertiliser stock solutions for greenhouse tomatoes grown in peat or bark modules.

Time of Application	Fertiliser	Stock Solution kg/10 l	Dilute Solution* N ppm	P ppm	K ppm
Planting to ripening	Potassium nitrate Urea	1.84 0.35	200	0	350
Ripening to mid October	Potassium nitrate Urea Monoammonium phosphate **or** Phosphoric acid (75%)	1.84 0.35 0.75 (0.52 l)	200	100	350
Mid October to harvest	Potassium nitrate Urea	1.32 0.50	200	0	250

* N, P and K concentrations resulting from a 1:200 dilution of stock solution.

Note: Addition of 0.5 kg Ensom salts, 0.33 kg of iron chelate (6% Fe) or 9 g of borax per 10 l of stock solution give concentrations of 25 ppm Mg, 10 ppm Fe and 0.05 ppm B, respectively, on dilution.

NURSERY STOCK, BEDDING PLANTS, AND POT PLANTS IN PEAT AND BARK

The nutrition of these plants is based on the use of slow release fertilisers. Liquid fertilisers are generally applied only occasionally but under conditions where leaching may occur they may need to be applied more frequently.

TESTING SOILLESS MEDIA

It is important that the nutrient levels in the growing media are monitored closely to prevent the development of nutrient disorders. Desirable nutrient levels for soilless media are given in Table 69.

Table 69: Desirable nutrient levels for soil-less media using 1:1.5 water extraction. Results expressed as ppm in extract.

Nutrient Level	Total Mineral N (NH_4-N + NO_3-N)*	P	K	Mg	Conductivity (mS)
Low	25	7	30	7	0.6
Desirable	51–77	15–31	59–85	15–22	1.3–1.8
High	101–125	35	114–140	30–36	2.8–3.6

* NO_3-N to NH_4-N ratio should be at least 3:1 for most plants.

For bark based compost half the P value given in Table 69 may be adequate. For seedlings, the desirable range is half the values for all elements. A pH of 5-6 measured in the water extract, is considered desirable for most crops. It may be necessary to reduce N to very low levels in autumn for outdoor nursery stock, including container grown kiwifruit, so as to harden them against winter frosts.

FERTILISER REQUIREMENTS

The quantity of base fertiliser for bedding plants, nursery stock and pot plants grown in bark and peat media is given in Table 70.

Plants growing in bark mixes generally require more Fe than those grown in peat. If an Fe deficiency is suspected, chelated iron (50-75 g/100 l) can be applied at a rate of 20-30 ml/pot.

The quantity of Osmocote® to be applied depends on the type of plant. For bedding plants and seedlings growing in a mix of four parts by volume of bark or peat to one volume of medium grade pumice, Osmocote® (14:6.2:11.6) or a similar slow release fertiliser should be applied at a rate of 2-3 kg/m³ of growing media. This rate can also be used for sensitive pot plants such as African violets or bougainvillea. A rate of 5 kg/m³ of growing media is satisfactory for other pot plants. For container grown nursery stock Osmocote® (18:4.8:8.3) or a similar 8-9 month slow release fertiliser can be used. A rate of 3-5 kg/m³ is recommended in this instance.

For acid requiring plants such as azaleas, rhododendron, and ericas the amount of dolomite should be reduced to 1 kg/m³ of potting mix. Other plants such as macadamia, kauri and silver beech (*Nothofagus menziesii*) also need a low input of lime, as well as the lower rate of Osmocote® (2-3 kg/m³).

For Proteas (*Leucadendron solignum* 'Red Bird' and *L.* 'Safari Sunset') a potting mix of 9 volumes of bark or peat and one volume of sterilised soil has been found to be successful with the base fertiliser input given in Table 71.

Table 70: Base fertiliser for bedding plants, nursery stock, and pot plants grown in bark and peat.

	Bark	N-composted Bark	Peat
Macronutrients (kg/m³)			
Dolomite	5–6	5–6	9–12
Superphosphate	1	1	1
Calcium ammonium nitrate	1	0.4–0.5	0
Osmocote®		See text	
Micronutrients (g/m³)			
Borax	11.8	11.8	11.8
Copper sulphate	21.2	21.2	21.2
Manganese sulphate	14.2	14.2	14.2
Sodium molybdate	2.4	2.4	2.4
Ferrous sulphate **or**	35.4	35.4	35.4
Chelated iron	(50)	(50)	(30)

Table 71: Base fertiliser for proteas grown in bark and peat.

	Rate
Macronutrients (kg/m³)	
Dolomite	2–3
Ammonium sulphate **or**	0.8
Calcium ammonium nitrate	(0.5)
Magnesium sulphate	0.2
Potassium sulphate	0.3
Osmocote® (19:2.6:8.3)	1–2
Micronutrients (g/m³)	
Borax	11.8
Copper sulphate	21.2
Manganese sulphate	14.2
Sodium molybdate	2.4
Ferrous sulphate **or**	35.4
Chelated iron	(50)

Other species including Banksia, Boronia, Grevillea, Macadamia, Leucospermum, Acacia and Callistemon should also grow well in this mix.

In addition to the incorporation of solid fertiliser to the potting mixes, a liquid fertiliser can be used to supplement the nutrition of the plants. The stock solution can be prepared by adding 4.4 kg potassium nitrate, 4.0 kg ammonium nitrate, and 800 ml (or 1480 g) phosphoric acid (88%) to 100 litres of water. Dilution rates suitable for the various plant types are given in Table 72.

Table 72: Dilution rates of stock nutrient solution for container grown nursery stock and pot plants.

Plant Type	Stock Solution Dilution Rate	Dilute Solution Concentrations ppm		
		N	P*	K
Slow growing (eg. Azaleas)	1:200	100	15	83
Medium and fast growing plants	1:100	200	30	166

* Exclude phosphoric acid for Proteas

For outdoor nursery stock an application once or twice a week is generally sufficient. For pot plants the solution should only be applied once a week. Where liquid fertilisers are applied over the entire plant, it must be washed off the leaves with water to minimise the risks of leaf scorch, especially in hot weather. Occasional double or triple strength solutions can be applied to plants in periods of wet weather to avoid the nutrient levels in the potting mixes being depleted by leaching.

FURTHER READING

Amos, J. (1980). Flowers and Ornamentals. Liquid feeding: basic requirements and formulations. New Zealand Ministry of Agriculture and Fisheries Aglink, HPP 171.

Prasad, M. (1985). Soilless mixes. Bark and sawdust for container grown plants. New Zealand Ministry of Agriculture and Fisheries Aglink, HPP 138.

V E G E T A B L E S

(R.J. Wood, I.S. Cornforth, J.A. Douglas, G.E. Malden, M. Prasad, G.J. Wilson)

The first part of this section describes the general conditions likely to result in nutrient deficiency or toxicity symptoms in vegetable crops. Methods of overcoming nutrient disorders are included.

The specific symptoms and nutrient requirements are then listed for each of the main species or families of vegetables.

PART 1

CONDITIONS ASSOCIATED WITH NUTRITIONAL DISORDERS IN VEGETABLE SPECIES

NITROGEN DEFICIENCY

Occurrence

Depends on the N supplying power of soils, N losses by leaching and N fertiliser use. Nitrogen deficiency is more common on soils with little organic matter; after repeated cropping with non-leguminous species; after heavy rain and irrigation causes either leaching in freely drained soils or waterlogging in heavier soils; when fresh organic residues have been incorporated into the soil; at low temperatures and with excessive plant populations (close spacing or weeds).

Species susceptability

Nearly all species are susceptable. Exceptions are well nodulated legumes although green beans may require fertiliser N even when nodulated. Requirements vary and are listed under each crop described. The requirements given are both the results of NZ experiments and from overseas. Where a range of values is given, the greatest rates are for maximum yields on the most responsive soils.

More fertiliser N is needed for winter crops than for summer ones. This is because of the cold conditions in winter and greater leaching losses at this time.

When large rates must be applied, it is usual to apply half at or before sowing and the remainder as a side dressing. In sandy soils where leaching is severe, frequent small dressings will be used more efficiently.

Treatment

If a deficiency is diagnosed, sidedress with a soluble N fertiliser (ammonium nitrate or urea) and water in if possible, or spray with 500-1000 litres/ha of urea solution (2 kg/100 l).

PHOSPHORUS DEFICIENCY

Occurrence

Acid or calcareous soils; high phosphate retention soils; peats; dry or cold conditions, especially at emergence.

Species susceptability

Species vary in susceptability. Olsen soil test values required at sowing time are given for each crop species. These can be achieved by applying the rates of P fertilisers indicated in Table 73. Asparagus appears to have the lowest P requirements and winter crops such as winter lettuce, spinach and early potatoes the greatest. Leeks and celery also require P-rich soils.

Treatment

There are no short term cures for P deficiency since the main requirement occurs at a very early stage of growth. Deficiency is avoided by starter fertilisers applied at rates to achieve the desired soil test status. These are used most efficiently if banded close to, but not in touch with the seed. If this is done, application rates can be decreased by 25-50%. The rates of fertiliser in Table 73 refer to water or citric soluble phosphates. Greater rates of water insoluble materials will be needed, but these are generally unsuitable where a rapid and large increase in soil test value is required. Target test values are achieved about four weeks after fertiliser has been applied. Subsequently test values will decline so that if the interval between topdressing and sowing is extended, fertiliser applications should be greater than indicated in Table 73.

POTASSIUM DEFICIENCY

Occurrence

On any heavily cropped soil with the possible exception of recent alluvial soils and some soils in the drier areas of the South Island (Brown-grey earths, dry yellow-grey earths, dry brown granular loams and clays and rendzinas). On other soils, soil test K values give a reasonable indication of supply. Large amounts of Mg or ammonium -N can decrease K availability.

Species susceptability

Target soil K test requirements are listed under each crop. They are influenced by soil texture. Corn and peas have relatively small requirements whereas celery, potatoes and tomatoes require considerably more. Target soil K test values can be achieved by applying rates of fertilisers calculated from data in Table 74.

Treatment

Potassium fertilisers are normally broadcast before sowing. Application rates can be decreased by 20-30% if the fertiliser is banded adjacent to seeds. Potassium chloride is normally used but potassium sulphate is preferable for chloride sensitive crops such as tomatoes, potatoes, celery, lettuce, beans and cauliflower. This is particularly important on light soils in low rainfall areas.

CALCIUM DEFICIENCY

Occurrence

Erratic and fairly rare. Can occur with soil test values less than 10. Other conditions include excessively wet or dry soils, high humidity and when available K, Mg or ammonium-N concentrations are very large.

Species susceptability

Celery and lettuce are most sensitive while brussels sprouts, cabbage and sweetcorn are rarely affected.

Treatment

Liming to required pH (see separate crops) is usually adequate. Avoid excessive soluble salts and soil compaction and irrigate regularly in dry conditions. Blackheart in celery can be controlled by spraying calcium nitrate (16 kg/1000 l/ha) or calcium chloride (8 kg/1000 l/ha) fortnightly.

3–5 Units	6–10 Units	11–15 Units	16–30 Units
Levin silt loam (76)	Karaka (88)	Kumeu clay (Trig Road) (45)	Templeton silt loam (CH) (9)
Egmont brown loam (93)	Kumeu peat (96)	Mapua loam (Nelson) (12)	Taitapu silt loam (5)
New Plymouth black loam (98)	Takapau sandy loam (69)	Templeton Eyre & Paparua (84)	Ranzau gravelly silt loam (19)
Ohakune loam (90)	Kumeu peat DSIR orchard (84)	Hastings clay loam (14)	Waimakiriri silt loam (CH) (6)
Katikati sandy loam (95)	Muriwai sand (42)	Waimakiriri sandy silt loam (Waimate) (3)	Putiki sandy loam (33)
	Patumahoe clay loam (56)	Waimea silt loam (Nelson) (13)	Kawhatau stoney loam (57)
	Westmere silt loam (53)	Havelock sandy loam on clay pan (19)	Meeanee
	Kiwitea silt loam (64)	Templeton silt loam (Waimate) (7)	Makaraka heavy silt loam
	Pukepuke sand (31)	Waimakiriri silt loam (Blh) (10)	Makaraka clay loam
	Hastings silt loam (30)	Kaiapoi silt loam (8)	Matawhero heavy silt loam
	Temuka black silt loam (34)	Twyford silt loam (11)	Matawhero clay loam
	Waimauku sand (41)	Twyford sandy loam	Waipaoa silt loam
	Kumeu clay DSIR Orchard (51)	Otiake silt loam (1)	
	Tikokino	Takapau stoney loam (26)	
		Ranzau stoney clay loam (30)	
		Barrhill sandy loam (6)	
		Putiki sandy loam (33)	
		Pakowhai silt loam	

Table 73: Increase of Olsen P units in the top 15 cm of soil as a result of broadcast application and incorporation of 1 tonne of superphosphate per hectare (10% P; 8% water soluble P). P retention values are given in brackets.

Table 74: Increase in K soil test units in the top 15 cm of soil as a result of broadcast application and incorporation of 100 kg K/ha.

1.5 Units	1.6–2.5 Units	2.6–3.5 Units
Mangere volcanic	Muriwai sand	Egmont brown loam
Kumeu clay (Trig Rd)	Waimauku sand	Westmere silt loam
Kumeu peat (DSIR)	Kumeu clay (DSIR)	Kawhatau stoney silt loam
Putiki fine sandy loam	Kumeu peat	Takapau sandy loam
Karapoti sandy loam	Patumahoe clay loam	Hastings silt loam
Takapau stoney loam	Kiwitea silt loam	Havelock sandy loam
Pukepuke sand	Twyford silt loam	Ranzau gravelly silt loam
Hastings clay loam	Mapua loam	Ranzau stoney clay loam
Waimea silt loam (Nelson)	Kairaki sand	Waimakiriri silt loam (Blh)
Mapua loam	Barrhill sandy loam	Templeton & Eyre/Paparua
Waimakiriri sandy silt loam (Waimate)	Temuka black silt loam	Templeton silty loam (CH)
Templeton silt loam (Waimate)	Kaiapoi sandy loam	Waimari peaty loam
Taitapu silt loam	Taitapu silt loam	
Waimakiriri silt loam (CH)	Levin silt loam	

MAGNESIUM DEFICIENCY

Occurrence

Symptoms tend to occur approaching maturity when yields may not be affected. Commonest on sandy soils and in wet conditions. Can be induced by excessive K in soils. Soil test values of 10-12 are adequate for most species but susceptible crops require 15.

Species susceptibility

Tomatoes, potatoes, cauliflowers and beans are sensitive to Mg deficiency.

Treatment

Diagnosed deficiencies can be treated by spraying with magnesium sulphate solution (2 kg/100 l).

SULPHUR DEFICIENCY

Occurrence

Rare in NZ although the continued use of high analysis fertilisers could result in deficiencies developing in soils prone to leaching and with little organic matter.

Species susceptibility

UK data indicate that brassica crops, leeks and radishes are most susceptible and beans, carrots, parsnips and celery are least likely to respond.

Treatment

Use S containing fertilisers such as ammonium sulphate and superphosphate. Elemental S can be used in areas prone to excessive leaching but it becomes available slowly and will acidify the soil.

MICRONUTRIENTS

The inclusion of micronutrients in the fertiliser programme is not routine for most vegetables. The most common deficiencies encountered are those of B and Mo in brassica crops. The deficiency occurs because soils contain inadequate supplies of these nutrients or because of pH affecting availability. Deficiencies of Mn, Fe, Zn or Cu are uncommon and are usually related to specific soils or situations.

Diagnosis of deficiency is not reliable from soil testing. Plant analysis is the recommended method of confirming a deficiency. Visual symptoms can be confusing in most cases and only a few situations have clear-cut symptoms.

To determine the need for a micronutrient to be added to a fertiliser programme, knowledge of the soil involved, susceptible crops and conditions conducive to deficiency is needed. This is summarised below.

Where a deficiency is diagnosed during crop growth, foliar applications usually give a good response. Rates of fertilisers to use are included below.

Excessive use of micronutrients should be avoided because toxicities can occur affecting plants or livestock grazed on cropping areas.

Boron

Susceptible soils:	Sands, loamy sands, sandy loams, high pH areas.
Susceptible crops:	Turnip, red beet, carrot, celery, cauliflower, broccoli, cabbage, tomato, asparagus, beans.
Treatment:	cultivate 1-2.5 kg B/ha into soil prior to sowing/planting. Foliar - apply borax 0.2-0.5 kg/100 l (may need hot water to dissolve) or use an equivalent amount of sodium borate which is more soluble (see Table 10).

Copper

Susceptible soils:	Organic soils.
Susceptible crops:	Onion, carrot, corn, cauliflower, lettuce, spinach, broad beans.
Treatment:	Soil — apply copper sulphate at 25-50 kg/ha when first cropped. Foliar — spray with copper sulphate 200-500 g/100 l/ha.

Iron

Susceptible soils:	Organic and podzolic soils, calcareous soils, soil pH greater than 6.7.
Susceptible crops:	Tomato, potato, beans, spinach.
Treatment:	Soil — apply ferrous sulphate at 20 kg/ha Foliar — iron chelates at 75-100 g/100 l

Manganese

Susceptible soils:	Podzols, organic soils, soil pH greater than 6.7.
Susceptible crops:	Tomato, beans, cucumber, squash, corn, red beet, radish, lettuce, peas.
Treatment:	cultivate manganese sulphate into soil at 20-30 kg/ha on mineral soils and 150-300 kg/ha on organic soils. Foliar — spray with manganese sulphate (200-400 g $MnSO_4$/100 l/ha).

Molybdenum

Susceptible soils:	Compacted sands, yellow-brown earths from greywacke, yellow-grey earths, soil pH less than 5.4.
Susceptible crops:	Brassicas, cucurbits, tomato, spinach, legumes.
Treatment:	Soil — correct soil pH; apply sodium molybdate at 0.5-2.0 kg/ha. Foliar — spray with sodium molybdate at 25-50 g/100 l/ha

Zinc

Susceptible soils:	Organic soils, wet soils, high pH
Susceptible crops:	Beet, beans, corn.
Treatment:	Soil — apply zinc sulphate at 10-15 kg/ha. Foliar — spray with zinc sulphate at 200-400 g/100 l/ha or chelated zinc compounds.

SOIL pH AND LIME REQUIREMENTS

Vegetable crops vary in their tolerance to soil acidity. Optimum pH ranges are given in the section on each crop.

Rates of lime required to increase the pH of soils of various textures are in Table 75.

Table 75: Lime rates required to increase soil pH by 1 unit in soils of differing texture.

Soil Texture	Lime Rate (tonne/ha)
Sand	2.5
Sandy loam	4.2
Silt loam	5.6
Clay loam	8.3
Clay	12.5
Peat	15

Notes

1. Lime is assumed to be 100% $CaCO_3$, for lower $CaCO_3$ content larger rates are needed.
2. Lime is assumed to have been thoroughly incorporated to 15 cm.
3. pH changes take 12-18 months for the increases indicated.
4. The rate of pH change depends on fineness of lime used and on moisture content of the soil. Lime in which a large proportion passes 0.5 mm mesh seive will react faster giving a quicker pH increase but a less lasting effect than a coarser sample. Under very dry conditions rates of pH change are slow.

PART 2

NUTRIENT REQUIREMENTS AND SPECIFIC DEFICIENCY SYMPTOMS OF VEGETABLE SPECIES

Nitrogen requirements are the total requirement for the crop; the actual fertiliser requirement is influenced by the N supplying power of the soil. This depends on soil type, cropping history and climate and is difficult to quantify. British work suggests that soils which were previously cropped with legumes, have been recently plowed out of pasture or have received moderate dressings of organic manures can supply the equivalent of 50 kg/ha fertiliser N while frequent heavy applications of organic manures or a lucerne crop can contribute up to 100 kg N/ha. The N supplying power of land frequently cropped with cereals or non-leguminous vegetables can probably be discounted when calculating N fertiliser requirements. The sap nitrate test described in the Appendix is potentially very useful in assessing the N status of plants during the first few weeks after emergence and hence the need for N fertiliser side dressings.

Optimum Olsen P and soil K values are given for each crop in the standard units used by the MAF soil testing service. The amounts of P and K fertilisers required to modify soil test values are in Tables 73 and 74.

The amounts of nutrients absorbed from the soil are given for each crop, together with estimates of the amounts removed in produce, where these data are available. Total uptake figures give a relative estimate of the overall nutrient requirements of a crop, although crops also vary in the efficiency with which they can absorb nutrients from the soil. Product removal values indicate the minimum amount of nutrients which must be replenished with fertilisers if soil fertility is not to decline. It must be remembered however that nutrient removal in produce is not the only source of nutrient loss from the soil. Leaching and fixation can be of equal importance.

Some of the nutrient removal data is based on recent trial work. Where the trial yields are significantly higher than normal commercial yields, the nutrient removal data can be reduced proportionately.

Commonly occurring nutrient concentrations in vegetable tissues are listed in the Appendix. It is important to recognise that while these may be characteristic values, values outside of these ranges do not automatically imply deficiencies or excesses.

Critical concentrations of NPK at various stages of growth are given for some species. They are derived from data given by Scaife and Turner (1983). They indicate minimum desirable nutrient concentrations in whole plant tops and demonstrate the marked changes in values which occur as plants develop; they also emphasise the need to consider plant age and development when interpreting tissue analysis data.

Optimum concentrations of nitrate –N in plant sap are also given for some species; the technique for measuring sap nitrate is described in the Appendix. This test is useful for differentiating between N and S deficiencies which often have similar leaf symptoms.

Deficiency symptoms are listed under each species when they either differ from the generalised symptoms for a particular element, such as the purple colouration of N deficient Brassica leaves, or when they are unique to a particular species or family of vegetables, such as whiptail in Mo deficient cauliflowers. Many of these descriptions are taken from Scaife and Turner (1983), which should be consulted for photographs of deficiency symptoms.

LEGUMINOSEAE (broad beans, peas, French beans, runner beans)

Nutrient requirements

Total nitrogen:

Broad beans	60 kg/ha
Green beans	80
Peas	40

Target Olsen P values:

	Soil P Retention		
	0–40	41–75	76–100%
Peas	30–35	36–45	46–55
Broad beans	35–45	46–55	56–75

Method of P application: Broadcast

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Peas	6	8	10
Broad and green beans	8	10	12

Method of K application: Broadcast

Optimum pH range: Beans 5.6–7.0
Peas 5.1–6.0

Nutrient uptake (kg/ha)

Crop	Yield	(tonne/ha)	N	P	K	Ca	Mg
Broad beans	haulm	15	70	8	57	22	5
	pods	2.2	80	13	49		
French beans	haulm	13.5	68	7	40		
	pods	16	54	9	43		
Peas	haulm	16	106	16	109		
	pods	9	58	7	24		

Tissue analysis

Commonly occurring but not critical values are in the Appendix.
Critical N, P and K concentrations (%) in whole plant tops:

		Plant Age (days)			
		40	80	120	160
Peas	N	4.0	2.4	–	–
	P	.38	.32	–	–
	K	2.7	1.8	–	–
Broad beans	N	3.8	3.2	2.8	2.0
	P	.38	.32	.27	.24
	K	1.9	1.7	–	–

Desirable N concentrations in youngest mature leaves (Levin):

	Age (weeks)	N%
Beans	7	3.5–4.0
	9–11	3.9–4.4

Sap nitrate concentrations in petioles of youngest mature leaves:

	Sampling period	NO_3–N (ppm)
Beans	150–200 mm tall (7–11 weeks)	500–750

Specific deficiency symptoms

Broad beans

- P Thin stems and erect leaves.
- S New leaflets erect.
- Ca Pods deformed, wilted and blackened; seeds do not develop.
- Mn Brown lesions on cotyledons.
- Zn Young leaves erect, pointed, tips curled back, rolled upwards and with wavey margins.
- Cu Brown patches in flowers which are paler than normal.
- B Interveinal chlorosis on middle-aged leaves.

Peas

- K Short internodes give squat plants.
- Fe Tendrils chlorotic, old leaves remain green.
- Mn Brown spots on cotyledons.
- Zn Lower leaves have necrotic margins, no flowers.
- Cu Normal seed pods but few seeds.
- B Vegetative shoots in main axils; few deformed seeds of variable size.

Green beans

- N Symptoms possible even when well nodulated.
- S Growth stops and golden yellow leaves fail to expand.
- Ca Wilting; pods deformed, seeds fail to develop.
- Mg Rusty bronzing of interveinal areas.
- Mn Brown patches on cotyledons.
- Zn French beans very susceptable. Symptoms appear soon after emergence; pale green chlorosis moves between veins from leaf tips to edges. Pods on terminal blossoms drop off.
- B Interveinal chlorosis on all leaves; young leaves small and curled. Pods deformed and split.
- Mn Toxicity — purple-black spots on veins, stem, petioles and midribs.

CRUCIFERAE (cabbage, cauliflower, brussels sprouts, turnip, swede, radish)

Nutrient requirements

Total nitrogen (kg/ha):

Winter cabbage	350
Brussels sprouts	290
Cauliflower	150–250
Winter sprouting broccoli	200
Summer cabbage	150–200
Swedes & turnips	120
Radish	100

Target Olsen P values:

	Soil P retention		
	0–40	41–75	76–100%
Cauliflower, cabbage, broccoli & radish	35–45	46–55	56–75

Method of P application: Banded for all except radish, swedes and turnips.

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Turnips, cabbage & radish	8	10	12
Broccoli & cauliflower	10	12	15

Method of K application: Banded for all except radish, swedes and turnips.

Optimum pH range:

Cabbage & brussels sprouts	5.6–7.0
Broccoli	6.0–7.2
Cauliflower	6.0–6.8
Turnips & swedes	5.4–6.7
Radish	6.0–7.1

Note that clubroot infection is diminished at pH greater than 6.5.

Nutrient uptake (kg/ha)

Crop		Yield (tonne/ha)	N	P	K	Ca	Mg
Broccoli		12	206	14	123	72	8
Brussels sprouts		15	246	22	134	55	1
Cabbage,	summer	70	181	22	141	177	11
	winter	69	203	19	112	155	10
	spring	45	123	25	146	137	10
Cauliflower	total	50	200	35	200	–	–
Swedes	foliage	16	104	12	82	–	–
	roots	58	252	26	149	–	–
Turnips	foliage	48	228	30	233	–	–
	roots	30	81	15	76	–	–
Radish	foliage	4	21	2	17	–	–
	roots	7.7	14	2	16	–	–

Tissue analysis

Commonly occurring, but not critical values are in the Appendix. In the tabulated information on critical concentrations that follows, the plant age (days) refers either to the number of days after transplanting, or to the number of days from emergence for crops that are directly seeded. Critical N, P and K concentrations (%) in whole plants:

		Plant Age (days)			
		40	80	120	160
Summer cabbage	N	5.2	3.5	–	–
	P	.59	.48	.39	.32
	K	4.3	2.8	1.9	–
Winter cabbage	N	4.5	4.0	–	–
	P	.47	.49	.52	.54
	K	4.3	2.8	1.9	–
Cauliflower	N	5.6	4.4	3.6	–
	P	.59	.48	.39	.32
	K	4.0	3.4	2.8	–
Brussels sprouts	N	3.8	3.2	2.8	2.0
	P	.38	.32	.27	.24
	K	3.0	2.7	2.4	2.2
Turnips	N	5.2	3.5	–	–
	P	.59	.48	.39	.32
	K	4.0	3.4	2.8	–
Swedes	N	3.8	3.2	2.8	2.0
	P	.50	.48	.46	–
	K	4.0	3.4	2.8	–
Radish	N	4.7	–	–	–
	P	0.51	–	–	–
	K	3.0	–	–	–

Desirable N concentration in youngest mature leaves (Levin):

	Age (weeks)	N%
Cabbage	6	> 5.2

Specific deficiency symptoms

Brassicas

- N — Leaves become bronzed, pink or purple.
- P — Muddy purple flush in old leaves; red curd in cauliflowers.
- Ca — Internal browning of brussels sprouts; internal tip burn in stored cabbage.
- Mg — Red tints may follow an interveinal chlorosis in the central region of older leaves.
- S — Primary and secondary veins form a blue-green pattern against a pale green background.
- Mn & Fe — Symptoms similar, distinguish by analysis.
- Zn — Cabbage leaves cupped with out-curved margins.
- B — Brassicas very sensitive. Swedes and turnips have multiple crowns and brown heart. Stems become hollow in cabbage, brussels sprouts and cauliflower. Cauliflower curds are brown.
- Mo — Brassicas very sensitive. Whiptail in cauliflowers. Cupping of leaves of young seedlings.

Radishes

- N — Older leaves pale green, these become yellow; veins and midribs red.
- P — Older leaves scorch at margins and wither early. Tendency to bolt.
- S — Cotyledons become purple and fall off, early bolting; root fails to swell.
- Ca — Young leaves cup backwards and have a marginal fringe of white spots which turn brown.
- B — Roots split or are very thin and misshapen.

CUCURBITACEAE (squash, pumpkins, melons, cucumbers, courgettes)

Nutrient requirements

As with many vegetables, nutrition during the first 2-3 weeks after emergence has a major effect on the final yields. Recent work from Pukekohe is included in this section; this indicates greater requirements for P and K for squash than earlier work.

Total nitrogen (kg/ha):

Squash & pumpkin	120–180
Melons	100
Marrows, courgettes	80
Cucumber	50

Target Olsen P values:

	Soil P Retention		
	0–40	41–75	76–100%
Cucumber, squash, marrow	35–45	46–55	56–75

Recent data from Pukekohe shows that maximum yields of squash were obtained with an Olsen test value of 130 on Patumahoe clay loam, suggesting that these target values are minimal.

Method of applying P fertilisers: Banded

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Marrow	8	10	12
Squash, pumpkins	10	12	15

Maximum yields were obtained with a soil K value of 17 on Patumahoe clay loam at Pukekohe.

Optimum pH range:

Cucumber	5.7–7.0
Marrow	5.6–6.7
Rock melon	5.6–6.8
Water melon	4.8–6.1
Pumpkin	5.6–6.7
Squash	5.6–6.8

Nutrient uptake (kg/ha)

Crop	Yield	(tonne/ha)	N	P	K
Cucumber	fruit	30	50	18	66
Cantaloupes	fruit	28	106	19	135
	vines	–	67	9	39
Honeydew melons	fruit	36	78	9	73
	vines	–	151	17	106
Squash	fruit	30	107	20	120

Tissue analysis

Concentrations of nutrients commonly found in Cucurbit leaves are in the Appendix. It is important to note that while these are characteristic values, concentrations outside the ranges given do not automatically imply deficiencies or excesses.

Sap nitrate concentrations in petioles of youngest mature leaves:

	Sampling period	NO_3-N (ppm)
Squash	Plant spread 50 cm (6 weeks after sowing)	1500
	Plant spread 100 cm, some flowers and small fruit (9 weeks)	700–1200
	Fruit up to 200 mm diameter	600–750

Desirable concentrations in youngest mature leaves:

	Age (weeks)	N%	P%	K%
Squash Delica (Pukekohe)	2	6.6	–	–
	5	6.5	1.1	4.7
	9	5.8	1.1	3.7
Rock melon (Levin)	9	>5.2	–	–

Specific deficiency symptoms

Marrow

- N & S Similar yellowing of older leaves, distinguish by sap nitrate test or S concentration.
- P Young leaves dull emerald green.
- Ca Young leaves claw shaped.
- B New leaves distorted, petioles have transverse cracks, fruit cracks. Leaf symptoms similar to cucumber mosaic virus; petiole cracks very diagnostic of B deficiency.

AMARYLIDICEAE (leeks, onions, garlic)

Nutrient requirements

Total nitrogen (kg N/ha):

Leeks	200
Spring onions	120–180
Onions & garlic	120

Target Olsen P values:

	Phosphate Retention		
	0–40	41–75	76–100%
Leeks & onions	45–55	56–75	76–90

Method of P application: Broadcast

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Leeks & onions	10	12	15

Method of K application: Broadcast

Optimum pH range:

Leeks 6.1–7.3
Onions 5.6–7.0

Nutrient uptake (kg/ha)

Crop	Yield (tonne/ha)	N	P	K	Ca	Mg
Leeks	150	293	29	298	110	17
Onions	48	107	17	88	16	4

Tissue analysis

Commonly occurring but not critical values are in the Appendix.

Critical N, P and K concentrations (%) in whole plants:

		Plant Age (days)			
		40	80	120	160
Spring onions	N	3.2	2.0	1.2	
	P	–	.41	.25	
	K	4.3	2.8	1.9	
Leeks	N	3.8	3.2	2.8	2.0
	P	–	.41	.34	.27
	K	–	2.3	1.7	1.4

Specific deficiency symptoms

Leeks

- S Leaves stiff and erect, early swelling of stem base.
- K Die back of old leaf tips.
- Ca Leaves very narrow and die back abruptly from tips without first yellowing.
- B Transverse cracks on leaves.

Onions

- S Leaves thick and deformed; new leaves yellow.
- K Older leaves die back from tip without becoming yellow.
- Ca As for K or death of a short length of leaf causing the distal part to fall over and die.
- Mg Older leaves uniformly yellow along length.
- Mn Striped chlorosis of outer leaves followed by necrosis; growth severely decreased.
- Zn Leaves striped yellow, twisted and stunted.
- Cu Tips of young leaves become chlorotic, turn white and twist or spiral. Bulb scales yellow and thin. Bulb soft.
- B Leaves crack transversely.
- Mo Poor emergence and seedling death. On mature plants tips die and there is a wilted zone between the dead tip and healthy tissue.

CHENOPODACEAE (red beet, spinach, silverbeet)

Nutrient requirements

Total nitrogen (kg/ha):

Winter spinach	350
Summer spinach	150
Red beet	150–250
Silverbeet	100

Target Olsen P values:

	Phosphate Retention		
	0–40	41–75	76–100%
Red beet	30–35	36–45	46–55
Summer spinach	35–45	46–55	56–75
Winter spinach	45–55	56–75	76–90

Method of P application: Broadcast

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Red beet	8	10	12
Spinach	10	12	15

Method of K application: Broadcast

Optimum pH range:

Red beet 6.0–7.2
Spinach 5.6–6.8

Nutrient uptake (kg/ha)

Crop	Yield (tonne/ha)	N	P	K	Ca	Mg
Spinach						
Hybrid 7	40	269	34	246	67	16
Prickly Supreme	16	85	12	81	35	10
Red beet foliage	22	102	26	103	–	–
roots	56	196	38	203	–	–

Tissue analysis

Commonly occurring values are in the Appendix.

Critical N, P and K concentrations (%) in whole plants:

		Plant Age (days)			
		40	80	120	160
Red beet	N	3.8	3.2	2.8	2.0
	P	.50	.48	.46	–
	K	7.0	4.4	2.7	–
Spinach	N	4.7	–	–	–
	P	.59	.48	.39	.32
	K	5.6	–	–	–

Specific deficiency symptoms

Red beet

N Purpling or yellowing of older leaves, depending on climatic conditions.
S Young leaves narrow, stiff and erect; yellowing and densely speckled with purple spots which eventually coalesce.
K Old leaves become flacid and die back from tip.
Ca Young leaves have purple-black hooked tips; leaf roll.
Mg Interveinal red mottles leading to brown blisters with purple edges. Late developing deficiency causes convex bubbling of lamina between veins.
Fe Young leaves bleached; older leaves have red tints.
Mn Leaves triangular with margins curled in and interveinal speckling.
B Canker — scattered black lesions in root flesh, sometimes with large black areas on the root surface.
Mo Patches of leaf die and become papery.

Spinach

P Reduction in growth with no other symptoms; extreme cases have dull, bronzed leaves.
S Older leaves have necrotic patches near tips.
K Papery necrotic patches and flaccid tips.
Ca New leaves small, distorted and chlorotic.
Mg Similar to K deficiency; distinguish by leaf analysis.
Zn Large irregular areas of sharply delineated, scorched papery tissue towards the tips of young leaves and subsequently interveinally on older leaves.
Cu Edges of young leaves become dull green, wilt and curve backwards.
B New leaves stubby and necrotic, older leaves die back from tips; and mature plants new leaves have a bubbled appearance.

COMPOSITAE (Lettuce)

Nutrient requirements

Total nitrogen (kg N/ha):

Summer lettuce 120–180
Winter lettuce 200–250

Target Olsen P values:

	Phosphate Retention		
	0–40	41–75	76–100%
Summer lettuce	35–45	46–55	56–75
Winter lettuce	45–55	56–75	76–90

Method of P application: Broadcast

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Lettuce	8	10	12

Method of K application: Broadcast; sulphate of potash preferred because of sensitivity to excess chloride.

Optimum pH range:

Lettuce 6.3–7.3

Nutrient uptake (kg/ha)

Crop	Yield (tonne/ha)	N	P	K	Ca	Mg
Summer lettuce	58	224	15	448	62	17
Winter lettuce	45	262	24	311	71	10

Tissue analysis

Commonly occurring values are in the Appendix.

Critical N, P and K concentrations (%) in whole plants:

		Plant Age			
		40	80	120	160
Lettuce	N	4.0	2.4	–	–
	P	.57	–	–	–
	K	4.3	2.8	1.9	–

Specific deficiency symptoms

P Reduced growth and failure to heart; no other symptoms.
S Stunting and rosetting.
Ca Puckering and necrosis of young leaf margins.
Mg Chlorotic marbling of older leaves which can be confused with virus infections; virus causes brittle leaves whereas Mg deficient leaves remain pliable.
Zn Papery necrotic areas with dark margins between veins on older leaves.
Cu Elongated cupped leaves; edges chlorotic and curl downwards; plants stunted, no heads form.
B Similar to Ca deficiency but tip necrosis becomes worse near the growing point which may be quite blackened; young leaves deformed with prominent mid ribs.
Mo Young plants pale green; older plants have translucent spots in older leaves.
Mn Irregular pale yellow margins on older leaves with sharp boundaries to rest of leaf.
B Toxicity — Regular yellow leaf margins in young

plants;
older plants may have brown-grey sunken spots which develop in a ring shaped pattern, veins dark brown, leaves become papery.

Cl Toxicity — Marginal scorch in wrapper leaves.

UMBELLIFERAE (carrots, parsnips, celery)

Nutrient requirements

Total nitrogen (kg N/ha):

Celery	350
Spring carrots	200
Carrots & parsnips	100

Target Olsen P values:

	Phosphate Retention		
	0–40	41–75	76–100%
Carrots & parsnips	35–45	46–55	56–75
Celery	45–55	56–75	76–90

Method of P application: Broadcast

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Carrots & parsnips	8	10	12
Celery	12	15	20

Method of K application: Broadcast

Optimum pH range:

Carrots	5.4–6.7
Parsnips	5.6–7.1
Celery	6.1–7.5

Nutrient uptake (kg/ha)

Crop	Yield	(tonne/ha)	N	P	K	Ca	Mg
Carrot	foliage	15	72	5	62	–	–
	roots	80	121	27	194	–	–
Topweight		79	242	34	313	121	24
Royal Chantenny		31	96	16	165	21	6
Parsnips	roots	44	146	36	183	–	–
Celery		80	307	79	984	228	38

Tissue analysis

Commonly occurring but not critical values are in the Appendix.

Critical N, P and K concentrations (%) in whole plant tops:

		Plant Age (days)			
		40	80	120	160
Carrots	N	3.2	2.4	1.8	–
	P	.38	.32	.27	.24
	K	4.3	2.8	1.9	–
Parsnips	N	3.8	3.2	2.8	2.0
	P	.59	.48	.39	.32
	K	5.0	3.8	2.8	2.2

Desirable N concentrations in youngest mature leaves (Levin):

	Age (weeks)	N%
Celery	8	>4.2

Sap nitrate concentrations in petioles of youngest mature leaves:

	Sampling period	NO_3-N (ppm)
Carrots	8 weeks from sowing	500–750
	10 weeks from sowing	400–600
Celery	8 weeks from transplant	750–900

Specific deficiency symptoms

Carrots

- N Uniformly pale yellow with fine leaflets.
- P No yellowing, old leaves purple. Distinguish from carrot fly attack by examining damage on tap root and from carrot 'mottley dwarf' virus by yellow young leaves and red or purple older leaves.
- S As for N, distinguish by plant analysis.
- K Old leaves scorched and collapse, later entire petioles look water soaked before drying and collapsing.
- Ca Water soaked appearance of petioles (like K) but more restricted, the distal part and leaf staying green initially. Roots may have a brown core.
- Mg Similar to N deficiency but red tints near margins and leaves not so fine; can also be confused with 'mottley dwarf' disease; distinguish by analysis.
- Mn Uniform pale yellowish-green; often patchy distribution in field.
- Cu Youngest leaves very dark green and fail to open.
- B Corky splits in petioles; roots split showing core, which may contain hollows.

Parsnips

- S New, pale leaves have sharply toothed margins and a fine network of recessed veins.
- Ca Water soaked petiole resulting in collapse of leaflets.
- Mn Marginal and interveinal chlorosis of most leaves; distinguished from Mg and K deficiency because chlorotic areas remain pale green rather than yellow and whole plant affected.
- B Older, pale leaves may have a red margin; section of root shows discoloration around the central xylem.

Celery

- N Older leaves ultimately become white.
- P Distinguish from N deficiency by sap nitrate test; P deficient plants will have a large NO_3-N concentration.
- S Distinguish from N, P and Mg by presence of symptoms on young leaves, rather than older, and nitrate sap test.
- Ca Black heart — blackening and death of growing point. Induced by excess of other cations (Na or K) or drought.
- Mg Distinguish from N deficiency by marginal chlorosis on intermediate leaves, as opposed to more uniform chlorosis with N deficiency.
- B Celery is susceptible to B deficiency, some varieties more than others. Symptoms include transversely cracked stems, formation of auxiliary shoots, distortion of young leaves, brown leaf margins and twisted petioles.

SOLONACEAE (tomatoes, potatoes, sweet peppers, aubergines)

Nutrient requirements

Total nitrogen (kg/ha):

Early potatoes	350
Main crop potatoes	100-150
Tomatoes, peppers, aubergines	120

Target Olsen P values:

	Phosphate Retention		
	0–40	41–75	76–100%
Tomatoes, main crop potatoes	35–45	46–55	56–75
Early potatoes	45–55	56–75	76–90

Method of P application: Potatoes banded, tomatoes broadcast.

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Potatoes and tomatoes	12	15	20

Method of K application: Potatoes banded, tomatoes broadcast.

Note that tomatoes are susceptable to chloride toxicity so that potassium sulphate is the preferred form.

Optimum pH range

Peppers	5.3–6.8
Aubergine	5.3–6.4
Potatoes	5.1–6.0
Tomatoes	5.3–6.7

Nutrient uptake (kg/ha)

Crop	Yield	(tonne/ha)	N	P	K
Potatoes	tubers	40	221	27	246
Tomatoes	fruits	75	112	11	202
	vines		90	12	112
Peppers	fruits	28	50	8	56
	plants		106	8	101

Tissue analysis

Commonly occurring but not critical values are in the Appendix.

Desirable N concentrations in youngest mature leaves (Levin):

	Age (weeks)	N%
Tomatoes	8	4.5–5.5
	10	> 3.7
Potatoes	10	5.3–6.3

Sap nitrate concentrations in petioles of youngest mature leaves:

	Sampling period	NO_3-N (ppm)
Tomatoes	6 weeks after transplant	900–1200
	10 weeks after transplant	600–800
	11 weeks after transplant	400–500
Potatoes	6-7 weeks after planting	2000 or more
	8-10 weeks after planting	1200–1600

Specific deficiency symptoms

Tomatoes

K	Small dry spots with brown margins appear in chlorotic areas on older leaves; margins become scorched and curled. K also influences fruit quality; ripening is uneven, fruit less acid and shape irregular if K is inadequate.
Ca	Blossom end rot can be induced by water stress, excessive use of ammonium–N and high K:Ca ratios.
Mg	Interveinal chlorosis of older leaves but may spread to younger leaves; can be induced by excess ammonium–N or K. May also be caused by waterlogging, disease, high soluble salts or stress of heavy fruit load.
Mn	Fine interveinal chlorosis on middle and older leaves; less severe than Fe deficiency and not confined to young leaves.
Fe	Young leaves become pale green or white but veins remain green.
B	Interveinal chlorosis in leaflets of older leaves leads to yellow and orange tints with yellow or purple veins; leaves and stems brittle.

Potatoes

P	Marginal leaf scorch with forward curling margins.
K	Leaves bluish green become bronzed with backward curling margins, interveinal spotting and marginal scorching.
Ca	Thin stems and small terminal leaves with chlorotic and inward curling margins; pink tints and tip death of leaflets; tubers dwarfed.
Mg	Central interveinal chlorosis followed by necrosis.
Fe	Young leaves chlorotic, veins may remain green.
Mn	Leaves remain green but have characteristic brown spots along veins; plants stunted.
B	Stunted growth, growing point killed.
B	Toxicity — Narrow brown marginal vein on leaves.

GRAMINACEAE (Sweetcorn)

Nutrient requirements

(See also Cornforth and Sinclair (1984) for nutrient requirements of maize.)

Total nitrogen (kg/ha):

Sweetcorn 90

Target Olsen P values:

	Phosphate Retention		
	0–40	41–75	76–100%
Sweetcorn	30–35	36–45	46–55

Method of P application: Banded

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Sweetcorn	6	8	10

Method of K application: Banded

Optimum pH range:

Sweetcorn	5.3–6.8

Nutrient uptake (kg/ha)

Crop	Yield	(tonne/ha)	N	P	K	Ca	Mg
Sweetcorn,	ears	16	62	9	34	–	–
	plants		112	13	84	–	–

Tissue analysis

Commonly occurring but not critical values are in the Appendix.

Desirable N concentration in stems (Levin):

	Age (weeks)	N%
Sweetcorn	6	>5.0

Sap nitrate concentrations in stem base:

	Sampling period	NO_3-N (ppm)
Sweetcorn	6 weeks from sowing	1100–1600
	8 weeks from sowing	600–1000

Specific deficiency symptoms

Sweetcorn

N	Pale green leaves with red-purple veins die back from tips; leaf sheaths purple; kernels fail to fill.
P	Uniform purpling of leaves; young plants susceptable but may subsequently recover; delayed silking and poor pollination gives irregular arrangement of grains. Distinguish from N deficiency with sap nitrate test. Cold weather also causes purpling.
S	New leaves uniformly yellow, old leaf bases red.
K	Marginal leaf scorch.
Ca	New leaves emerge with dead tips or tips may fail to emerge; tips of several leaves may remain joined together; leaf edges serrated and curled.
Mg	Parallel yellow white stripes between green veins on older leaves followed by red or purple colours on tips and edges.
Fe	Yellow striping of new leaves which may become bleached.
Mn	White streaks between green veins; streaks may turn brown.
Zn	Broad bands of pale tissue appear in the lower half of emerging leaves in young plants, distinguish from Fe and Mg deficiencies which cause full length stripes, silking delayed and pollination poor, stem nodes reddish-brown.
B	Thick, brittle leaves with many raised stripes; short internodes; barren or partly barren ears with pointed tips.

LILIACEAE (Asparagus)

Nutrient requirements

Total nitrogen (kg/ha):

Asparagus 120

Target Olsen P values:

	Phosphate Retention		
	0–40	41–75	76–100%
Asparagus	20–25	26–30	31–35

Method of P application: Broadcast

Target K values:

	Soil Texture		
	Sand	Loam	Clay
Asparagus	10	12	15

Method of K application: Broadcast

Optimum pH range:

Asparagus 6.4–7.5

Nutrient uptake (kg/ha)

Crop	Yield	(tonne/ha)	N	P	K	Ca	Mg	S
Asparagus	Spears	7.6	31	4	20	2	1	4
	Fern	24	53	4	36	30	6	-

Tissue analysis

Commonly occurring, but not critical values are in the Appendix.

FURTHER READING

Cornforth, I.S. and Sinclair, A.G. (1984). *Fertiliser and Liming Recommendations for Pastures and Crops in New Zealand. Second Revised Edition.* New Zealand Ministry of Agriculture and Fisheries, Wellington, pp. 76.

Lorenz, O.A. and Maynard, D.N. (1980). *Knott's Handbook for Vegetable Growers.* A. Wiley Interscience Publications, New York, pp. 390.

Scaife, A. and Turner, M. (1983). *Diagnosis of Mineral Disorders in Plants. Vol. 2. Vegetables.* (Robinson, J.B.D., Ed), HMSO, London, pp. 96.

A P P E N D I X

1. MEASUREMENT OF SAP NITRATE FOR VEGETABLE CROPS

This simple method of nitrate sap testing can be used to increase the efficiency of N fertiliser use. The technique is still at an experimental stage but the work is sufficiently advanced for advisors and growers to use it on a trial basis.

Sampling

Take samples from several plants to get an average value. The most suitable plant part to sample is indicated under individual crop species. Samples should be taken between 10 am and 2 pm and preferably in sunny conditions.

Sap extraction

Chop the plant parts into pieces 5 mm long and put them into a garlic press. Squeeze out the sap and let the drops coalesce together (to get a representative sample) before putting it onto a Merck nitrate test strip. Wipe away any excess.

Measurement of Nitrate

Begin timing colour development as soon as the strip is moistened by sap. After two minutes compare the purple colour of the strip with the coloured squares on the container. To convert ppm nitrate to ppm nitrate-N, divide by 4.4. If the strip colour is darker than the darkest colour on the container, record the time at which the strip colour is equal to the 500 ppm colour and convert to ppm using Appendix Table 1.

Appendix Table 1: Data for using Merkoquant test strips for measuring nitrate–N concentrations greater than 100 ppm.

Seconds to Darkest Colour	NO_3-N ppm
6	2500
8	1600
10	1100
12	950
14	800
16	700
18	620
20	540
22	490
24	440
26	400
28	370
30	340
35	280
40	230
45	210
50	180
55	170
60	155
65	150
70	140
80	130
90	120
100	115
110	115
120	114

Interpretation

Desirable concentrations of nitrate-N in plant sap are given for those species for which data are available. Values fluctuate with the supply of N from the soil so that several measurements may be desirable. This is a very sensitive indicator of plant N status.

2. DIAGNOSTIC STANDARDS FOR PLANT NUTRIENT CONCENTRATIONS IN VEGETABLES

Appendix Table 2: Typical concentrations (%) for foliar analysis of vegetables*

Crop	Cultivar	Time of Sampling	Plant Part	N	P	K	Ca	Mg
Asparagus	Unknown	Mature	Fern from 45–90 cm up	2.4–3.8	0.30–0.35	1.5–2.4	0.4–0.5	0.15–0.2
Asparagus	Mary Washington 500	January	Fern from 45–90 cm up	3.0–4.2	0.24–0.36	1.5–2.4	0.3–1.1	0.11–0.2
Asparagus	Mary Washington 500	February	Fern from 45–90 cm up	2.6–3.9	0.22–0.39	1.7–3.1	0.6–1.5	0.14–0.2
Asparagus	Mary Washington 500	March	Fern from 45–90 cm up	2.3–3.1	0.16–0.24	1.5–2.7	0.6–1.5	0.14–0.2
Asparagus	Mary Washington 500	April	Fern from 45–90 cm up	1.0–1.8	0.06–0.15	0.8–1.5	0.4–1.1	0.07–0.1
Asparagus	Mary Washington 500	May	Fern from 45–90 cm up	0.9–1.6	0.03–0.08	0.6–1.0	0.5–0.9	0.06–0.1
Beans (snap)	Unknown	Bud	Young mature trifoliate leaf	3.0–6.0	0.25–0.50	1.8–2.5	0.8–3.0	0.25–0.70
Beans (dwarf)	Processor	6–8 weeks	Young mature trifoliate leaf	4.2–6.4	0.24–0.40	2.1–3.0	1.8–3.1	0.24–0.43
Beans (dwarf)	Processor	10–12 weeks	Young mature trifoliate leaf	3.3–4.6	0.26–0.35	1.0–2.1	2.7–3.5	0.32–0.37
Beans, French	G.V. 50			4.2–4.7	0.25–0.33	2.0–2.7	2.2–2.9	0.7 –1.0
Beans (Broad)	Exhibition long pod	12–13 weeks	YML	4.5–5.6	0.25–0.40	1.3–2.2	0.6–0.9	0.16–0.26
		17–18 weeks	YML	4.2–6.2	0.20–0.40	2.2–2.8	0.7–1.8	0.10–0.3
Beetroot	Unknown	Mature	YML	3.5–5.0	0.20–0.30	2.0–4.0	2.5–3.5	0.30–0.8
Beetroot	Detroit	9–11 weeks	YML	4.9–5.9	0.30–0.50	3.0–5.0	1.1–2.5	0.40–0.8
Beetroot	Detroit	Roots 4–7 cm diameter	YML	4.7–5.4	0.28–0.55	4.5–4.7	0.4–1.0	0.80–0.9
Broccoli	Wollhan 29	9–10 weeks	YML	6.0–7.1	0.40–0.70	1.4–4.3	2.0–5.0	0.15–0.27
Broccoli	Unknown	Heading	YML	3.2–5.5	0.30–0.70	2.0–4.0	1.2–2.5	0.23–0.4
Brussels Sprouts	Unknown	Unknown	Upper leaves	2.2–4.2	0.26–0.45	2.4–3.4	0.3–2.2	0.23–0.4
Brussels Sprouts	Jade Cross D	13 weeks	YML	4.3–4.9	0.36–0.41	2.6–3.0	2.8–3.2	0.16–0.2
Brussels Sprouts	Jade Cross D	17 weeks	YML	3.9–4.5	0.27–0.33	1.4–3.0	2.2–2.7	0.13–0.1
Cabbage	Unknown	Heads ½ grown	Young wrapper leaf	3.0–4.0	0.30–0.50	3.0–4.0	1.5–3.5	0.25–0.4
Cabbage	Erlicross Hybrid	8 weeks	YML	5.0–5.6	0.40–0.50	2.9–3.5	1.7–2.9	0.18–0.2
Cabbage winter	Erlicross Hybrid	12–13 weeks	YML	4.3–4.7	0.40–0.50	2.7–3.5	1.6–2.6	0.16–0.2

Crop	Cultivar	Time of Sampling	Plant Part	N	P	K	Ca	Mg
Cabbage spring	Flower of Spring	16–17 weeks	YML	5.4–6.2	0.50–0.70	3.0–4.0	2.0–5.0	0.12–0.30
Cabbage spring	Flower of Spring	21–22 weeks	YML	4.2–5.4	0.40–0.60	2.0–3.0	2.0–5.0	0.12–0.30
Cabbage summer	Golden Acre	7–8 weeks	YML	4.1–5.4	0.30–0.50	2.9–4.7	2.5–3.9	0.19–0.35
Cabbage summer	Golden Acre	11–12 weeks	YML	3.2–5.0	0.20–0.40	2.4–4.2	1.6–5.0	0.15–0.22
Capsicum	Californian Wonder	14 weeks	YML	4.5–5.0	0.17–0.25	5.2–6.2	3.0–5.0	0.48–0.72
Capsicum	Unknown	Mid growth	YML	3.0–5.0	0.30–0.70	4.0–5.4	0.4–0.6	1.00–1.70
Carrots (autumn)	Unknown	4 months	YML	3.2–3.6	0.32–0.36	3.0–5.0	1.2–1.6	0.15–0.18
Carrots (autumn)	Unknown	5½ months	YML	2.6–3.5	0.26–0.42	3.0–5.0	1.2–1.6	0.15–0.21
Carrots (spring)	Topweight	9–10 weeks	YML	3.9–4.7	0.25–0.47	3.0–4.8	1.0–2.0	0.19–0.32
Carrots (spring)	Topweight	13–14 weeks	YML	2.2–4.3	0.20–0.47	2.5–4.1	1.0–2.2	0.15–0.32
Carrots	Unknown	Mid length	YML	1.8–3.5	0.20–0.40	2.0–4.0	2.0–3.5	–
Carrots	Red-cones Chantenay	Roots 1–3 cm diameter	YML	2.4–2.9	0.19–0.27	1.3–1.7	1.0–1.5	0.36–0.46
Cauliflower	Snow White	13 weeks	YML	5.6–6.1	0.53–0.63	2.5–3.0	2.0–3.0	0.14–0.18
Cauliflower	Unknown	Buttoning	Leaf blade	3.0–4.5	0.54–0.72	3.0–3.7	0.72–0.79	0.24–0.26
Corn, sweet	Golden Cross Bantam	8 weeks	YML	3.4–4.2	0.30–0.42	1.5–2.5	0.5–0.8	0.15–0.25
Corn, sweet	Unknown	Silking	Ear leaf	2.6–3.5	0.20–0.30	1.8–2.5	0.15–0.30	0.20–0.30
Cucumber	Burpeana Hybrid	8–10 weeks	YML	4.2–5.4	0.30–0.70	2.8–3.4	2.5–0.45	0.30–0.60
Celery	unknown	½ grown	YML	2.5–4.0	0.30–0.60	3.5–5.5	0.4–1.5	0.20–0.50
Garlic	Unknown	6½ months	YML	3.2–4.0	0.20–0.30	3.2–4.0	0.7–1.1	0.11–0.20
Leek	Musselburgh	6 months	Leaf	3.7–4.3	0.26–0.34	3.1–4.1	1.0–1.4	0.14–0.18
Lettuce	Yates Lake	Singling	Plant	4.2–5.0	0.32–0.40	7.3–8.3	1.2–1.7	0.23–0.31
Lettuce winter	Triumph	9–11 weeks	YML	4.0–5.5	0.40–0.60	4.5–5.5	1.0–1.7	0.14–0.27
Lettuce	Unknown	heads ½ size	Wrapper leaf	2.5–4.0	0.40–0.60	6.0–8.0	1.4–2.0	0.50–0.70
Marrow	Blockjock Hybrid	6–8 weeks	YML	4.5–6.3	0.40–0.80	2.9–3.3	1.6–3.0	0.24–0.60

Crop	Cultivar	Time of Sampling	Plant Part	N	P	K	Ca	Mg
Onion	Pukekohe Longkeeper	18–19 weeks	YML	2.9–4.1	0.27–0.42	1.8–3.6	1.4–2.4	0.15–0.23
Onion	Unknown	Mid growth	YML	–	0.25–0.40	–	–	–
Parsnip	Hollow Crown	12 weeks	YML	4.6–6.3	0.44–0.58	3.0–5.1	0.9–1.7	0.20–0.50
Peas	Victory Freezer	7 weeks	YML	3.6–5.1	0.26–0.48	2.0–2.5	0.8–1.8	0.14–0.24
Peas	Unknown	Mid growth	YML	2.7–3.8	0.25–0.35	1.5–3.0	1.5–2.5	0.25–0.40
Peas	cv S.S.F.	Late flowering, 70 days	Whole tops	2.8–5.3	0.30–0.45	0.8–1.4	0.9–1.4	0.73–0.87
Potato	Ilam Hardy	8–9 weeks	YML	5.7–6.3	0.40–0.50	3.5–4.4	1.4–2.0	0.46–0.63
Potato	Ilam Hardy	13–14 weeks	YML	4.1–4.3	0.19–0.21	2.5–3.2	1.9–2.3	0.60–0.78
Potato	Unknown	Tubers ½ grown	YML	3.0–5.0	0.20–0.40	4.0–8.0	1.5–2.5	0.50–1.5
Radish Autumn sown	Early Scarlet Globe	8 weeks	YML	5.2–5.8	0.40–0.50	2.0–2.6	2.7–3.3	0.20–0.22
Radish Spring sown	Early Scarlet Globe	8 weeks	YML	5.9–6.4	0.45–0.55	3.9–5.1	3.3–3.7	0.35–0.40
Rhubarb	Crimson Winter	6½–7 months	Leaf	3.2–4.4	0.20–0.40	2.1–4.2	0.8–1.7	0.30–0.80
Rhubarb	Crimson Winter	6½–7 months	Stem	1.2–2.1	0.07–0.20	1.9–3.4	1.2–3.7	0.09–0.14
Silverbeet	Ford Hook		YML	4.4–5.3	0.3–0.7	2.0–6.0	0.6–3.0	0.3–1.3
Spinach (spring)	Prickly Long Standing	8 weeks	YML	4.7–5.7	0.44–0.52	3.0–4.0	1.4–2.4	0.4–0.5
Spinach (autumn)	Prickly Supreme	7–8 weeks	YML	4.1–6.1	0.7–0.8	3.4–6.3	1.6–2.6	0.3–0.9
Spinach	Unknown	4–7 weeks	YML	4.2–5.2	0.48–0.58	3.5–5.3	0.6–1.2	1.6–1.8
Spinach	Unknown	Mature	YML	4.0–6.0	0.03–0.05	3.0–4.0	0.6–1.0	1.6–1.8
Squash	Buttercup Bush	6–8 weeks	YML	4.6–5.6	0.36–0.72	2.0–4.0	2.7–5.5	0.14–0.45
Sweet potatoes	Unknown	mid season	YML	3.2–4.2	0.20–0.30	2.9–4.3	0.73–0.95	0.40–0.80
Tomato	Unknown	12 weeks	YML	4.5–5.8	0.28–0.46	3.1–5.1	1.5–4.4	0.30–0.55
Tomato machine	Unknown	1st mature fruit	YML	3.0–6.0	0.50–0.80	2.5–4.0	4.0–6.0	0.60–0.90
Tomato staked	Unknown	1st mature fruit	YML	4.0–6.0	0.80–1.0	3.0–5.0	1.4–1.8	0.4–0.6
Tomato trellised	Unknown	Mature fruit	YML	2.5–4.0	0.30–0.60	3.0–4.0	0.5–2.0	0.6–1.0
Turnip	White Stone	7 weeks	YML	5.3–6.1	0.50–0.60	3.1–3.9	2.4–3.0	0.11–0.21
Turnip	White Stone	10 weeks	YML	3.5–5.0	0.40–0.60	2.3–3.3	1.3–2.2	0.14–0.21
Turnip	Unknown	Mid growth	YML	3.5–4.5	0.35–0.60	–	3.0–5.0	–
Watermelon	Unknown	Mid growth	YML	2.0–3.0	0.20–0.30	2.5–3.5	2.5–3.5	0.6–0.8

Sulphur: Desirable concentrations approximately 0.4–0.5%
Micronutrients: Normal ranges are (ppm): Mn, 50–500; Fe, 50–500; Zn, 30–100; Cu, 5–30; B, 40–100.
* Nutrient concentrations in crops, where cultivar names are given, are based on fertiliser trial work done in NZ; others are from overseas sources.

3. FACTORS FOR CONVERTING MAF QUICKTEST RESULTS TO OTHER UNITS

Reporting Unit	Note	Ca	K	Mg	P	S
μ g/ml in extract		Ca × 25	K × 4	Mg × 1	P × 0.05	S × 0.2
μ g/ml in soil	1	Ca × 113.6	K × 18.2	Mg × 4.55	P × 1.0	—
μ g/g in soil	2	Ca × 125	K × 20	Mg × 5	P × 1.1	S × 1
kg/ha — 75 mm	3	Ca × 85.2	K × 13.6	Mg × 3.4	P × 0.75	S × 0.68
me/100 g	4	Ca × 0.955	K × 0.070	Mg × 0.048	—	—
me/100 g	5	Ca × 0.625	K × 0.051	Mg × 0.042	—	—

1. Soil: extractant ratio 4.4:20 (v/v) for Ca, K, and Mg. 1:20 (v/v) for P.
2. Approximate conversion for Ca, K, Mg and P based on a constant bulk density of 0.91 g/ml for prepared soil; note that this can vary between soils. Soil extractant ratio for S is 1:5 (w/w).
3. Assuming a constant bulk density as prepared soil (except S).
4. Assuming a constant bulk density of 0.91 g/ml and using experimentally determined relationships with exchangeable cations (determined at pH 7).
5. Theoretical conversion from μ g/g soil, assuming constant bulk density of 0.91 g/ml and 100 percent extraction.

FURTHER READING

Cornforth, I.S. and Sinclair, A.G. (1984). *Fertiliser and Liming Recommendations for Pastures and Crops in New Zealand. Second Revised Edition.* Ministry of Agriculture and Fisheries, Wellington, pp. 76.

4. FREQUENTLY USED UNITS, ABBREVIATIONS AND CONVERSION FACTORS

g	grams
μ g	micrograms (10^{-6} g)
mg	milligrams (10^{-3} g)
kg	kilograms (1 kg = 100 g)
ha	hectares (10 000 m^2)
ml	millilitre (1 litre = 1000ml)
μ g/g	= mg/kg = ppm (parts per million)
μ g/ml	= mg/kg = ppm (parts per million)
w/w	weight per weight
v/v	volume per volume

1 lb/acre	= 1.121 kg/ha
1 cwt/acre	= 125 kg/ha
1 ton/acre	= 2.5 tonnes/ha
100 kg	= 1.968 cwt
1 g/m^2	= 10 kg/ha

FURTHER READING

Prasad, M. and Spiers, M. (1984). A simple sap test for measuring nitrate in vegetables. *Southern Horticulture, 16:* 43-44.