5.8 FERTILIZATION OF NUTS

5.8.1 MACADAMIAS

Macadamia nuts have been cultivated commercially in South Africa for many years with the first commercial plantings in the late 60's/early 70's.

The nutrient requirements of macadamia trees are closely correlated with their phenology. The phenological cycle is more or less as follows:

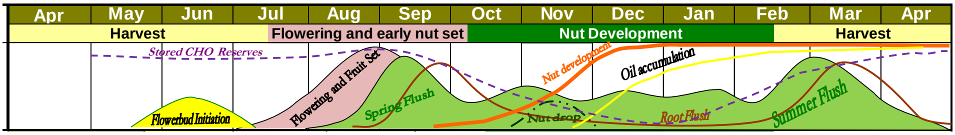

Fig. 5.8.1: Typical macadamia phenological cycle in South Africa (Mayo Macs Technical Services)

- May/June: Flower initiation.
- August/September: Main flowering.
- September/October: Nut set.
- November: Nut drop
- November to January: Nut development and oil accumulation. Nut growth increases linearly up to the middle of December, thereafter the nuts convert starch into oil. The oil accumulation period is very important since nut quality is directly dependent on the oil content.
- March-July: Mature nut drop period. This varies between cultivars and seasons.

MACADAMIA NUTRITION

Macadamia trees cannot tolerate poor nutrition. The first signs of deficiencies are typically a decrease in production and nut quality, followed by a gradual deterioration of the tree's health, with fewer sparsely distributed leaves. When extreme nutrient deficiencies occur, branches start to die off, resulting in sunburn damage on exposed branches and trunks. Ultimately, if the nutritional problems are not addressed, the loss of trees is inevitable.

Macadamias require well-drained soil with a pH (H_2O) 1:1 paste of 5.5-6.5 (ARC-ITSC) or 4.5-5.5 (pH KCl). The N, P and K levels should be replenished as required by the tree, as indicated by leaf analysis and removal of nutrients by the crop. Micronutrient levels should likewise also be monitored regularly and replenished where necessary.

The timing and level of nutrient application are both very important. Nutrients can be applied as inorganic compounds or single-element fertilizers or as organic fertilizers. The latter are less constant in their chemical composition but are nevertheless a valuable source of plant nutrients (micro- as well as macro-elements) and improve soil buffering (more resistant to changes in soil chemical, physical and biological properties). It is sound policy to make use of both inorganic and organic sources of plant nutrients.

Soil and leaf analyses

Soil and leaf analyses are useful tools in planning a fertilizer programme. Useful norms are given in Tables 5.8.1.1 and 5.8.1.2.

Table 5.8.1.1. Leaf analysis norms

Element	Norm
N	1.2 – 1.6%
P	0.08 – 0.10%
K	0.6 – 0.7%
S	0.18 – 0.25%
Ca	0.6 – 0.9%
Mg	0.08 – 0.10%
Na	< 0.02%
Cl	0.03 – 0.05%
Cu	5 - 10 mg kg^{-1}
Zn	15 - 50 mg kg^{-1}
Mn	100 - 1000 mg kg^{-1}
Fe	40 - 200 mg kg^{-1}
B	40 - 75 mg kg^{-1}

	N(%)	P(%)	K(%)	S(%)	Ca(%)	Mg(%)	Zn(ppm)	Mn(ppm)	Fe (ppm)	Cu (ppm)	B(ppm)
Deficient	0.3-0.8	<0.05	0.06-0.34	<0.10	<0.3	<0.05	<9	<20		<3	8-12
Low	0.9-1.19	0.05-0.06	0.35-0.49	0.10-0.19	0.3-0.5	0.05-0.08	9 - 14	20-149	<25	3-4	13-49
Sufficient	1.2-1.59	0.07-0.09	0.50-0.70	0.20-0.30	0.6-0.9	0.09-0.11	15-50	150-1000	25-200	5-12	50-90
High	1.6-1.8	0.10-0.15	0.71-1.20	>0.30	1.0-1.1	0.12-0.20	>50	1600-3000		20-70	>90
Excessive	>2.0	>0.15	>1.20		>1.1	>0.20		3600-5500			

Source: Mayo Macs norms **Adapted from SAMAC and Hewitt & Vimpany, 2007**

Table 5.8.1.2. Soil analysis norms

Element	Method of extraction	Ideal level
pH (H_20)	1:5 soil:water	At least 5.5-6.5
pH (KCl)	10 mL soil : 25 mL 1*M* KCl	4.5-5.5
0rganic carbon	Walkley-Black	4%
Nitrate nitrogen	1:5 water extraction	25 mg kg^{-1}
Sulphate sulphur	Phosphate extraction	20 mg kg^{-1}
Phosphorus	Bray 1	30 mg kg^{-1}
	Bray 2	20-80 mg kg^{-1}
	Ambic	14-34 mg kg^{-1}
	Resin	10-20 mg kg^{-1}
Potassium	Exchangeable	(80-150ppm) 260 mg kg^{-1}
Calcium	Exchangeable	(400-1 000) 1500 mg kg^{-1}
Magnesium	Exchangeable	(100-200) 210 mg kg^{-1}
Sodium	Exchangeable	< 5% (ideally <2) of exchangeable cations on $cmol_c$ kg^{-1} basis
Acid saturation	Exchangeable	0-1% (acceptable up to 5%)

Source: SAMAC (amended, Cedara, Mayo Macs)

Leaf sampling

Leaf samples should be taken from October to November. Take the young fully developed leaf of the third or fourth pair of leaves from the growth point on a main lateral branch. Sample healthy trees only. Sampled leaves should not be diseased, damaged or exhibit nutrient deficiency symptoms. Sample leaves from the same cultivar.

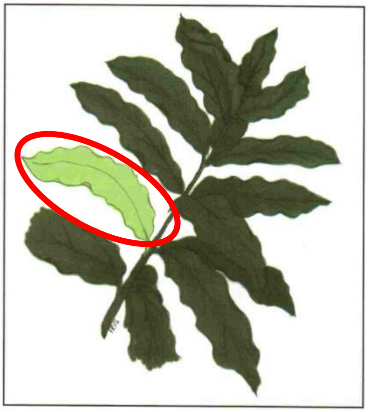

Fig 5.8.2: Red circle indicates the correct leaf to be sampled. Image courtesy of The Cultivation of Macadamias (ARC-ITSC).

Organic matter

Low levels of soil organic matter often result in the deterioration of the soil structure and tree condition. In practice, orchards are constantly mulched with grass from inter-row areas, as well as finely chopped leaves and branches from pruning, in order to keep the organic matter content of the soil as high as possible. When the organic carbon content of the soil drops below 1.5%, urgent steps need to be taken to rectify the problem, for example, adding manure.

In soils with a low clay content, high levels of organic carbon matter are essential. In these soils, the organic material represents a large part of the cation exchange capacity (CEC).

Pre-plant soil preparation

It is important to conduct a thorough on-site field inspection and assessment where macadamias are to be planted. Identifying soil differences, in conjunction with soil analyses, will indicate the required pre-plant action. Deep ripping may be required to eliminate compaction. Low soil pH and low soil-test values for K, Ca, Mg and/or P would indicate the essential pre-plant corrective measures with potassium fertiliser, agricultural lime and/or phosphorus fertilizer, particularly as these elements are relatively immobile in soils. As a general guideline, in the event of a very low soil P, one ton of superphosphate (10.5% P), or alternatively 500 kg MAP and 500 kg gypsum ha^{-1} should be broadcast and incorporated into the soil. Again, deep ripping may be required.

Phosphorus (P)
Phosphorus deficiencies are indicated by:

- Yellowing of leaves on the sunny side of the tree.
- Sun-scorched leaves high up in the tree as well as on the western side of the tree.
- Defoliation of the tips of branches and poor leaf density.

Annual application of phosphorus at one fifth of the annual nitrogen requirement of 7 to 10 g per tree for every year of the age of the tree, is usually sufficient. If P-sufficiency is indicated by either leaf analysis (0.08 to 0.10% P), or soil-P levels higher than 30 mg kg^{-1} (Bray 1 method), then additional P-applications may be detrimental to the trees. An application of 50 kg P ha^{-1} should suffice where deficiencies exist. High soil P levels have a detrimental effect on iron (Fe) and zinc (Zn) availability often leading to deficiencies on these two elements.

Nitrogen (N)

Generally, soil and leaf analyses are conducted to determine the N-status of an orchard. When the recommended leaf norm ranges between 1.2% and 1.6%, an annual application per tree of 25 g to 50 g N for each year of the age of the tree, is recommended – up to a maximum of 500 g per tree from year 10 onwards. Excessive N-applications can be detrimental and could result in the following:

- Excessive tree size without any significant increase in production.
- Wind damage associated with excessive vegetation growth.
- Lanky growth and trees with a weak framework.
- Increased susceptibility to copper (Cu) deficiency, common in the coastal production areas.

Nitrogen requirements depend on the age of the tree, its current growth stage, and the size of the crop harvested.

Young trees up to three years

These trees require constant replenishment of nitrogen to ensure optimum growth and a strong framework. Young trees have little or no reserves, and nitrogen supplements should be applied monthly throughout the year.

Beginning of reproductive phase, 3 to 4 years

The number of applications may now be reduced. Too much N at this stage may delay the beginning of nut bearing.

Reproductive or production phase, 4 years and older

The amount of nitrogen should be aimed at maximising production without over-stimulating vegetative growth and split into 4-5 applications. In producing orchards, N is supplemented only between April and December. Vegetative growth hampers nut growth and oil accumulation in the period January to March.

Potassium (K)

Potassium is supplemented regularly to maintain optimum soil-K levels, especially with the use of organic fertilizers that are mostly too low in K. K-application should commence in late winter to early summer with peak levels being applied in October to December to ensure sufficient levels for new growth and development of nuts. Potassium improves nut quality.

Apply K in a ratio of 1:1 with N, up to and with nut bearing age. From about the fifth year, apply K in a ratio of between 1.25 and 1.5 with N.

Applications of K to soils high in exchangeable K (>600 mg K/L, or >15% of ECEC) may be detrimental because high rates of K uptake may reduce Mg and Ca uptake.

Calcium (Ca)
If soil acidity is a problem, this should be rectified before planting. Lime should be broadcast and incorporated deep into the soil.

Macadamia roots are highly sensitive to high pH-values in the topsoil. Surface applications of lime should therefore be avoided as far as possible, especially in the case of young trees. In older orchards, the pH may be adjusted by applying 500 to 1 000 kg lime ha^{-1}.

The availability of Ca may be measured using the ratio of Ca to Mg plus K. An excess of the one could result in reduced availability of the other two. High applications of potassium fertilizers result in low uptake of Ca from the soil.

Magnesium (Mg)
Magnesium is an important part of the chlorophyll that makes photosynthesis possible and promotes carbohydrate production in the plant.

Magnesium is therefore important to macadamias as a high carbohydrate content is essential for the accumulation of oil in the nuts. High applications of potassium fertilizers result in low uptake of Mg from the soil.

Sulphur (S)
Sulphur deficiencies seldom occur in practice, as sufficient quantities are usually supplied by sulphur-containing fertilizers and organic materials added as mulch.

Micro-elements
Deficiencies of boron, zinc and copper readily occur in macadamia orchards. Iron deficiencies may occur in soils with a high pH and high soil P. Manganese deficiencies are rare.

Boron (B)
Boron deficiency is a common occurrence in macadamia orchards and hampers flower and fruit formation. Where deficiencies do occur, foliar applications containing 0.25 g B l^{-1} between September and December give good results; up to four sprays may be necessary. Soil application of boron at 0.15 g m^{-2} below the leaf canopy can also be considered as an alternative when a deficiency is indicated by leaf analyses.

Warning: An excess of boron is highly toxic to plants. Applications should not exceed recommended doses and preferably use slow release forms.

Zinc (Zn)
Zinc is important in phosphorus metabolism and in the regulation of water consumption.

Zinc deficiencies may be induced or aggravated by high P-applications, especially in spring and early summer, when rapid growth takes place and when zinc is not readily taken up because of low soil temperatures. Soil applications of zinc at 10g Zinc sulphate m^{-2} below the leaf canopy (or 2g Zinc EDTA chelate m^{-2}) can be considered when a deficiency is indicated by leaf analyses. Foliar sprays of zinc sulphate (250-400 g/100l) or zinc amino acid or EDTA chelated products at 100-125 ml/100l water are also used.

Zinc deficiencies lead to the following:

- Retarded growth or cessation of growth as a result of low auxin levels in the tissues.
- A rosette of the terminal growth of shoots and buds, with resultant small and weak leaves.
- Abnormal thickening of roots.
- Light yellow colour of the new growth. Viewed close-up, the veins are green and the rest of the leaf appears chlorotic.

Copper (Cu)

Where deficiencies are indicated by soil and leaf analyses, copper sulphate may be applied to the soil at a rate of 30 kg ha^{-1} or foliar sprays of Copper amino acid or EDTA chelated products at 50-100ml 100 l^{-1} water.

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