THE WORLDWIDE BUSINESS FORMULA

CropKit

Specialty Plant Nutrition Management Guide
Mango

POWERED BY ELEMENT Q SQM

Dr Steven A. Oosthuyse (PhD)

www.sqm.com

I hereby would like to thank Harmen Tjalling Holwerda (SQM Europe) for his facilitation of the publication of this document.

Dr Steven A. Oosthuyse (PhD)

Foreword

SQM is a major supplier of specialty plant nutrition products and related services to distributors and growers around the world.

As part of its commitment to the agricultural community, SQM has developed a comprehensive series of **Crop Kits**. Each Crop Kit consists of a Specialty Plant Nutrition Management Guide, a PowerPoint presentation and a CD containing many relevant pictures.

These guides compile the results of yearlong research and development activities, as well as the practical experiences of the company's specialists from around the world, in order to provide comprehensive **Specialty Plant Nutrition Management Information** to SQM's distributors, agronomists, growers and farmers.

This **Mango Nutrition Management Guide** summarizes the main market requirements and the nutrient management needed to produce high yields of top quality mangoes.

More information is available through SQM agronomists or SQM's alliance partner Yara. SQM recognizes that there is no universal blueprint for mango production – hence no detailed plant nutrition programme is included in this guide. However, by working together with your local agronomist you can be sure to achieve excellent crop performance. For area specific programmes consult your local SQM distributor or agronomist.

This guide, which has been developed with the full support of the world's leading specialty plant nutrition specialists, is part of a range of the most comprehensive **Specialty Plant Nutrition Management Guides** available.

Table of Contents

Introduction

The aim of this Mango Nutrient-Status Management Guide is to provide pertinent information enabling SQM's business partners to effectively manage mango tree nutrient status. Information is also provided to enable the reader to gain an understanding of mango tree culture.

Crop phenology, required growing conditions, and nutritional balance as it relates to fruit quality, are dealt with. Consideration is given to the main roles of the macro- and trace elements as they relate to tree growth and function. Some nutrient deficiency and excess imbalances are also given attention. Tree fertilization promoting the accomplishment of the ideal balance between the essential nutrients is considered.

Chapter 1 provides the basis for nutrition management as it relates to orchard performance in terms of revenue generation. Chapter 2 furnishes general information concerning mango growth and development, soil and climatic requirements, diseases, harvest maturity determination, and quality assessment. The essential roles of the nutrients requiring management are presented in Chapter 3. Guideline data enabling effective nutrition management is presented in Chapter 4. Chapter 5 comprises photographs facilitating the diagnosis of various visual excess and deficiency nutrient imbalances. Chapter 6 provides practical information concerning tree fertilization for soils differing in a number of key characteristics. In Chapter 7, some pertinent research results are presented. The literature cited is presented in Chapter 8.

Note on booklet value-expression convention:

(.) Period: indicates thousands.
(,) Comma: demarcates the place of the decimal.
The number 1.500,5, stated in words, is "one thousand five hundred and five tenths."

1 Nutritional Status as it Relates to Tree Performance

Tree performance, considered in terms of revenue generation, relates fundamentally to tree health, being in turn a function of the extent to which nutrient levels in the various tissues are in balance for a particular growth stage. A reduction in performance will occur if imbalance exists, both with respect to deficiency (deficiency imbalance) and excess (excess imbalance). As a result of the general removal of mineral nutrients from the orchard via fruit harvest, soil nutrient leaching, the removal of prunings, and water run-off, nutrient replenishment is generally required to rectify balance. Nutrient status management generally entails the supply of the mineral nutrients requiring management in the correct proportions and at opportune development stages.

An ideal fertilization programme is one that enables the nutrient-status balance to be perfectly maintained during the organ building processes characterizing mango tree growth and development. Guideline data, procured from focused research, can be used to facilitate decisions concerning the supply of nutrients in relative and quantitative terms. Guideline data can take the form of leaf nutrient concentration norms. Such norms are relevant to leaves sampled at a particular stage of maturation and according to a prescribed method.

Nutrient accumulation estimates, whether absolute or relative (nutrient accumulation in terms of inclusion in the various organs as growth and development occurs), can also serve as valuable information to maintain balance. Soil attribute and nutrient status norms are also useful. It is noteworthy that the provision of guidance data be such that its procurement is from superior performing trees.

Fertilizers, whether applied on the above-ground parts (via spraying) or to the soil, should be viewed as nutritional-balance management tools. Fertilizer formulations differ vastly in their ability to alter plant nutrient status, certain of which are more effective than others.

Tree revenue generation relates to yield and fruit quality. Fruit quality relates directly to the attributes desired by the target market. Guideline data should be procured from superior performing trees, in terms of revenue generation. Orchard revenue bears a direct relation with the extent to which the target market preferences are met as well as orchard yield.

2 Key Issues Relating to Mango Tree Culture

2.1 Nomenclature

Common names: Mango, manga (Tamil), mangga (Philippines, Malaysia, Indonesia), manguier (France).

Tree: Symmetrical, evergreen tree ranging in height from 8 to 25 metres and bearing simple leaves and drupe fruits of variable size (Figures 1 and 2). Fruits grow during the summer months and are borne on terminal inflorescences developing during spring.

Family: *Anacardiaceae*.

Scientific name: *Mangifera indica L.*

Figure 1. *A well-formed three-year-old mango tree at a stage just prior to flowering.*

Figure 2. *Tommy Atkins mango trees bearing fruits nearing the stage of harvest maturation.*

2.2 Rainfall, Diseases and Soil-Water Management

Mango trees are drought tolerant and can withstand temporary flooding. Rainfall distribution during the year has a marked effect on tree performance. Wet conditions during the flowering and fruit development period are detrimental, promoting diseases, both in the fruits and tree. Under wet and humid conditions mango inflorescences and fruits are susceptible to bacterial black spot (*Xanthomonas cam-pestris*) (Figures 3 and 4), anthracnose (*Colletotrichum gloeosporioides*) (Figures 5, 6 and 7), blight (*Botryosphearia spp.*) (Figures 8 and 9) and soft-brown rot (*Botryosphearia spp.*). Contrastingly, powdery mildew (*Oidium mangiferae*) inflorescence colonization (Figure 10) is generally prevalent when conditions are dry.

Figure 3. *Bacterial black spot lesions on an unripe Keitt mango. Star-like lesions develop. Once developed they weep, exuding sap.*

Figure 4. *Bacterial black spot lesions on mango leaves.*

Figure 5. *Anthracnose "tear-stain" lesions on an unripe mango.*

Figure 6. *Anthracnose lesions on a mature, but unharvested Keitt fruit.*

Figure 7. *Anthracnose lesions developing on a ripe (left) and on an unripe (right) Van Dyke fruit.*

Figure 8. *Soft-brown rot at the stem-end of a Kent fruit.*

Figure 9. *Blight lesions on a young Keitt mango, and totally "blighted" fruitlets (adjacent). Fruit-drop is often associated with partial blight fruit-colonization.*

Figure 10. *Powdery mildew on Tommy Atkins inflorescences. Mono-potassium phosphate (MKP), a potassium-phosphate fertilizer, spray applied at 1% (w/v), is effective in controlling this disease.*

Tree water demand varies appreciably in relation to growth stage during the seasonal cycle. Demand is substantially increased in trees just having produced a new flush, or being in flower, or having set a crop. The water need of trees possessing newly developing inflorescences is particularly high. Water demand monitoring (for example, with tensiometers) and water application (irrigation) based on need during a particular stage are essential to avoid inflorescence wilt or fruit drop. Tensiometer irrigation-scheduling (Figure 11) is superior in managing soil water content where the soil clay content exceeds 10%. Scheduling based on the data obtained from a Neutron Probe, Deviner or Class A Pan can be adopted where the soil clay content is less than 10%.

Figure 11. *A tensiometer station comprising a 30, a 60 and a 90 cm "reading-depth" tensiometer. Irrigation management based on tensiometer readings is most effective in managing soil-water availability in mango. The clay content of the soil must be sufficiently high (> 10%) for tensiometer installation.*

The imposition of a "relative" drought stress prior to flowering is only necessary in regions not experiencing sufficient winter-cold for adequate flower induction. Mango trees should not be exposed to a soil-water deficiency stress (indicated by tensiometer readings of less than - 45 kpa) unless the winter conditions are marginally inductive (daily temperature minima exceeding 15°C).

The number of tensiometer stations installed in an orchard will depend on the variation in soil type and cultivar across the orchard blocks comprising the planting. A tensiometer station should minimally comprise a 30 and a 60 cm "reading depth" tensiometer. Soil-water management is based on the readings of the 30 cm tensiometer, and the duration of an irrigation cycle, on the readings of the 60 cm tensiometer. The "suction" pressure should not be permitted to exceed - 45 kpa if soil-water stress is not to be experienced by the trees.

Mango leaves are susceptible to salinity damage. Where the soil and water are saline (EC > 2,0 dS/m), irrigation management should be primarily geared to the avoidance of salt-burn (Figure 12).

Figure 12. *Mango leaves are susceptible to salinity damage (salt-burn). Irrigation management, where the soil and water are saline, should be primarily geared to salinity damage avoidance.*

2.3 Soil Suitability

Mango trees can be grown in a wide range of soil types. It should be noted that high soil pH is particularly limiting. Mango trees are generally not able to tolerate pH levels in excess of 8. In high pH soils, growth is curtailed, and trace-element deficiency symptoms develop shortly after transplanting. Deficiency imbalances have strong influence on fruit quality.

Figure 13. *Internal breakdown in "Hindi". It is noteworthy that a tree's nutritional status bears a strong relation with the nutritional status of the soil in which the tree grows. Soil characteristics such as pH also affect a tree's nutritional status. In turn, a tree's nutritional status bears a strong relation with the nutritional status of the fruits on the tree. Fruit nutritional imbalances may result in the development of internal breakdown, as shown here.*

Cultivation in loams or sandy loams favours enhanced skin ground-colouration during ripening and a reduced incidence of fruit-pulp breakdown (jelly-seed or soft-nose) (Figure 13). Fruit quality tends to be inferior where the soil nitrogen content is high. Soils rich in clay are considered to be inferior due to their enhanced capacity to retain ammonical nitrogen.

Ammonium, specifically, is adsorbed by soil-colloids (clay and organic matter) and is thus released into the soil solution over a prolonged period. Ammonium fertilizers should be used moderately where the soil clay content is high. Excessive applications of manure also disfavour fruit quality, this being due to the prolonged release of nitrogen resulting for manure degradation.

Soil pH levels from 5,5 to 7,0 are considered to be ideal (Nakasone and Paull, 1998). In acid soils, lime (calcitic, or dolomitic if the soil magnesium content is low) should be incorporated to a sufficient depth (at least 80 cm) to rectify soil pH prior to planting (Figure 14). Furthermore, the soil should contain sufficient phosphate at planting. Applied phosphate should concurrently be incorporated to the same depth.

Figure 14. *Soil pH and the soil phosphorous content should, in particular, be rectified before planting.*

2.4 Tree Growth and Development

Mango trees grow discontinuously, size increases resulting from vegetative flushes arising periodically (Figure 15). New shoots or inflorescences (Figure 16) develop, the type of organ arising depending largely on the environmental conditions experienced at a critical stage occurring shortly after apical-meristem activation. Tree size-increase is limited during flowering and fruiting, since the inflorescences are determinate and vegetative flushing is inhibited when reproductive organogenesis is occurring. The extent of inhibition is commensurate with flowering intensity and crop-load.

Figure 15. *Canopy size-increase occurs discontinuously due to the periodic initiation of vegetative flushes.*

Figure 16. *Terminal inflorescence development occurs when environmental conditions change; terminal inflorescences becoming inductive (inflorescence-development inducing).*

Root growth precedes flushing. Apical dominance is generally strong, with new growth occurring only from the apical bud on the terminal shoots. In trees retaining the vegetative state, a number of buds in the bud-whorl terminating the shoots develop after a number of growth flushes have occurred, this resulting in "eventual" branching (terminal branching)(Figure 17). The number of flushes arising prior to multiple bud-break varies greatly between cultivars. Multiple breaks generally occur during the initiation of every flush in Heidi, whereas in Keitt, multiple breaks may only occur after five or six growth flushes.

Figure 17. *Upright growth resulting from continued linear growth initially. Branching eventually occurs as a result of multiple terminal breaks (note branching at apex of branch).*

In all varieties, terminal branching occurs in every terminal shoot having produced an inflorescence or number of inflorescences (Figures 18 and 19). The inflorescences themselves are determinate, however, vegetativeness not occurring as a continuance of development.

Figure 18. *After terminal inflorescence development, new shoots are produced laterally from buds close to the point of inflorescence attachment.*

Figure 19. *Post-harvest branching at the location of prior inflorescence emergence.*

After periods of coolness or coolness in association with a degree of drought stress, terminal inflorescence development occurs. Temperatures of 20°C to 30°C favour vegetative flushing, whereas those from 6°C to 18°C favour inflorescence initiation (Davenport and Nunez-Elisea, 1997). Fruits set on the inflorescences (Figure 20). Lateral bud development on terminal shoots bearing fruits is inhibited until harvest or just before. In trees bearing a heavy fruit load, growth may be limited to one flush after harvest. In trees failing to retain a significant quantity of fruits due to reduced flowering, the yearly size increase may be substantial due to the occurrence of flushing during flowering and the fruit growth and development periods – flushing occurring in the non-flowering terminal shoots.

Figure 20. *Fruits set on the inflorescences. Lateral buds are inhibited from developing on fruit-bearing terminal shoots.*

In the situation of adequate soil water availability and non-stressful evaporative demand, ambient temperatures determine the frequency of flushing; new shoot development becoming less frequent when daily temperatures drop during autumn and winter. Mango trees can become exceptionally large, attaining heights in excess of 25 metres. Yearly pruning (branch heading) of productive trees is required to keep canopy-size in check, thereby preventing over-crowding and yield decline. Canopies or canopy-sections, well exposed to sunlight 70 to 90% of sunlight hours, are the most productive (Figure 21).

Figure 21. *Canopy height and width control will ensure perpetual cropping due to sustained canopy exposure to sunlight.*

2.5 Fruit Harvest-Maturation Assessment

Non-uniform stage of development or maturation of fruits is a problem in regions where flowering is non-synchronous, or where more than one "inflorescence flush" occurs during late winter or spring. Where between-tree variation in flowering time is clear, colour marking of the trees to differentiate them regarding the week of full-bloom can be useful in assessing the time-of-harvest for groups of trees.

Fruit harvest maturation is generally assessed on pulp colouration in terms of its transition from white-green to yellow (Figure 22). Yellow colouration of the pulp (mesocarp) from seed (endocarp) to skin (exocarp) generally indicates readiness to harvest. Fruits harvested too early ripen normally if not exposed to chilling temperatures. However, taste is poor due to an excess of acids relative to simple sugars on full ripening. On the other hand, progressed maturation is generally associated with excessive fruit drop, increased disease, increased physiological disorder incidence (where nutritional management is at fault) and splitting. Fruits of a cultivar harvested late in the season are generally more appealing in taste due to a markedly increased sugar to acid ratio (Oosthuyse, 1996).

Fruit-pulp colouration-charts have been produced to facilitate the determination of the ideal stage to harvest fruits of a range of cultivars (Oosthuyse, 1991). Other indicators, such as degree of shoulder development or extent of lenticel corking (browning), are also useful in assessing stage to harvest (Figures 23 and 24).

Figure 22. *Harvest maturation is assessed on pulp colouration. An even yellow colouration indicates readiness to harvest in Kent, for example. The relationship between readiness to harvest and pulp colouration extent, differs with respect to cultivar.*

Figure 23. *The occurrence of clearly raised shoulders on the fruit indicates readiness to harvest in many varieties. The degree to which fruit become round from being oblong can also serve as an indication of stage of maturation.*

Figure 24. *Clear yellowing or browning of the skin-lenticels indicates readiness to harvest in a range of cultivars. Tommy Atkins (shown here) is a candidate.*

2.6 Fruit Quality Assessment

On ripening, fruits remaining free of disease and physiological (internal) disorder symptoms, fruits becoming sufficiently sweet, and fruits whose green ground-skin colour becomes entirely yellow, are considered to be of good quality by consumers in the European Union. Post-harvest disease occurrence is the major factor affecting quality and shelf-life, generally.

Tree nutritional status has a marked effect on quality. This is evidenced by quality being strongly influenced by the soil in which trees are grown, and by the nutrition and irrigation practices carried out. Fertilization procedures favouring the accomplishment of the desired nutrient balance, for which leaf nutrient concentration norms serve as a reference, are required to maximize tree performance.

In sampling leaves to determine the leaf dry weight concentrations of the nutrients requiring management, certain guidelines must be followed. Leaves are sampled in November (southern hemisphere) or in May (northern hemisphere) and are removed from fruit bearing terminal shoots.

3 Primary Roles of the Mineral Nutrients Requiring Management in Mango

In general, nutrition management entails the management of the tree status of nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), copper (Cu), iron (Fe), zinc (Zn), manganese (Mn), boron (B) and molybdenum (Mo). Carbon (C), hydrogen (H) and oxygen (O) are additionally essential for growth, being required in the greatest quantities and constituting most of the biomass resulting from growth and development (90% +). However, these nutrients are obtained from the atmosphere and water; their usage-rate in a given environment depending largely on the efficiency of soil-water and nutrition management.

Nitrogen, phosphorous and potassium are referred to as macro-nutrients. Calcium, magnesium and sulphur are called major-nutrients, whereas copper, iron, manganese, zinc and boron are referred to as micro-nutrients. Molybdenum may be categorized as a “trace-trace” nutrient. This nomenclature indicates the extent of use by the tree. Table 1 shows the nutrient requirement in grams per 1.000 g of N required by a Tommy Atkins mango fruit (Oosthuyse, 1999).

Table 1. *Nutrient requirement (elemental) of a Tommy Atkins mango fruit in grams per 1.000 grams of nitrogen required (average fruit weight: 598 g).*

Nutrient	Mass in grams
Nitrogen	1.000,00
Phosphorous	215,79
Potassium	1.568,26
Calcium	182,60
Magnesium	141,25
Sulphur	123,40
Copper	1,56
Iron	8,54
Manganese	3,43
Zinc	2,99
Boron	4,12
Molybdenum	0,01

Certain nutrients are mobile in the phloem (the living translocation system of the tree), whereas others are not. Nitrogen, phosphorous, potassium, magnesium and molybdenum are phloem mobile, whereas sulphur, copper, iron, manganese, zinc and boron are immobile or sparingly phloem-mobile. This aspect dictates whether deficiency first occurs in young developing tissues or in older organs. As the phloem mobile nutrients can be translocated from developed parts of the tree to the sites of meristematic activity, their deficiency is always noted first in older tissues, typically in the older leaves. The converse is true for the nutrients that are phloem immobile; deficiency occurring first in the young developing tissues.

The nutrients requiring management are either used for the formation of organic compounds (proteins, carbohydrates, enzymes, nucleic acids), or have a direct regulatory role in tree growth and function. The following summarizes some of their functions.

3.1 Nitrogen

Nitrogen is a component of many structural, regulatory and energy compounds, it arising in amino acids, proteins, nucleotides, phospholipids, energy transfer compounds (adenosine phosphates) and enzymes. It is also a component of chlorophyll, which imparts stems and leaves with their green colour; chlorophyll being a key component of the photosynthetic apparatus. Nitrogen supply is of particular concern after harvest for the support of new shoot growth; these shoots being accountable for carbohydrate reserve replenishment during the autumn and winter months, as well as bearing the following season's reproductive organs (inflorescences and fruits). Nitrogen is mobile in the phloem, and hence, can be translocated from older leaves to active meristems, for example.

3.2 Phosphorous

Phosphorous is a component of structural and energy transfer compounds, being found in phospholipids and adenosine phosphates. It is also a component of nucleotides, the building blocks of DNA and RNA. Phosphorous supply is of particular concern during periods of root development and during flowering and early fruit development. Phosphorous is mobile in the phloem, and hence, can be translocated between tree organs.

3.3 Potassium

Of the supplied nutrients, potassium is required in the greatest quantity by productive mango trees. Potassium does not become a structural component of a plant-synthesized compound. It has a highly significant role in facilitating the transport of metabolites in plants, being involved in the transfer of carbohydrates from leaves to expanding fruits (Figure 25) and in the movement of nitrogen in the phloem. Its importance regarding metabolite transport is evidenced by its relatively high concentration in the phloem. Potassium also plays an important role in stomata aperture size regulation, and thus tree water loss. Its presence has been associated with increased fibre strength, enhanced photosynthesis, increased cold and drought tolerance, and increased stem rigidity. Superior fruit quality, which in turn bears a relation with efficient plant functionality, is associated with adequate potassium uptake and favourable supply. Sufficient accumulation in the tree during the period preceding flowering is vitally important, since root supply is unable to meet demand during the rapid period of fruit growth. Potassium is highly mobile in the phloem.

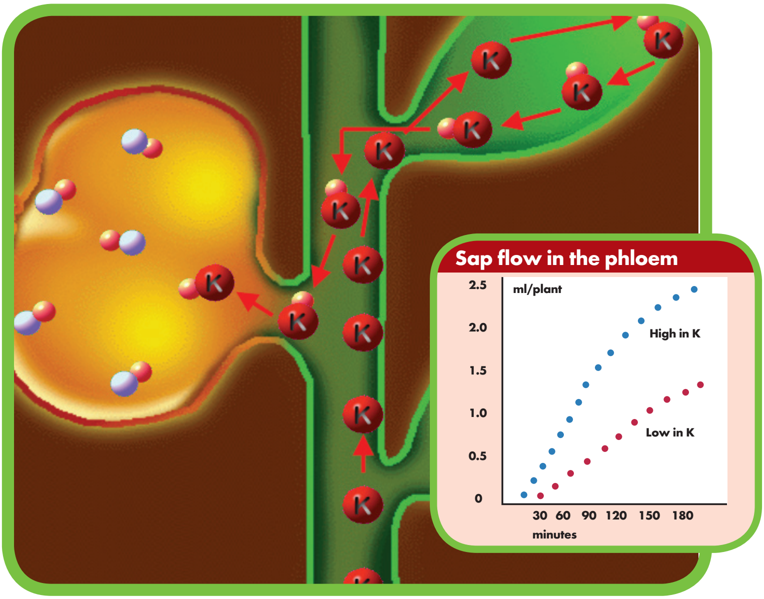

***Figure 25**. Diagrammatic representation of the movement of potassium up through the xylem to the leaf, and then from leaf to fruit through the phloem with carbohydrates attached.*

3.4 Calcium

Calcium is an essential component of the cell wall and membranes, imparting integrity (resistance to breakdown or attack) to the cells. Hence, calcium should be in sufficient supply at all of the sites of meristematic activity. Calcium is immobile in living tissues, and for this reason, its supply throughout the plant is totally reliant on the supply of root-acquired water. Breaks in water supply give rise to breaks in calcium supply to the regions where growth and development is occurring. Calcium has also a role to play in promoting the formation of proteins.

3.5 Magnesium

Magnesium is most well known for its position and role in being a component of the chlorophyll molecule. Magnesium also has an important role to play in facilitating the translocation of phosphorous. Magnesium is highly mobile in the phloem.

3.6 Sulphur

Sulphur is a component of the amino acids, methionine, cysteine, thiamine and biotin, which often comprise many parts of proteins and enzymes. Sulphur is involved in chlorophyll formation. It is relatively immobile in the phloem; its supply to the growing parts of the plant thus being dependent on water distribution and availability.

3.7 Copper, Iron, Manganese, Zinc, Boron and Molybdenum

There is considerable variation in the specific roles of the various trace elements in plant growth processes. A common role is that of participation in enzyme systems. Enzymes are the directors of plant chemistry. Hormone balance affects gene expression, the genes coding for the necessary enzymes required at any one stage.

Copper (Cu), iron (Fe) and molybdenum (Mo) can act as electron carriers in enzyme systems bringing about oxidation-reduction reactions. Zinc (Zn) and manganese (Mn) function in enzyme systems important for plant metabolism. Molybdenum (Mo) and Mn are important in certain N-transformations. Mo is a component of the enzyme nitrogenase, essential for the process of nitrogen fixation, and is present in the enzyme nitrate-reductase, being responsible for the reduction of NO_3^- in plants. Zn plays a role in protein synthesis (enzymes being proteins, and proteins also being "make-up" components of plants), in the formation of some growth hormones, and in the reproductive processes of certain crop-plants. Cu is involved in photosynthesis and respiration, as well as in the use of Fe. Cu stimulates lignification of plant cell walls. B is a structural component of pectin and lignin. It plays a role in the translocation of carbohydrates and phosphorous across membranes, and in the absorption of certain cations. B deficiency is associated with reduced water absorption, root growth and sugar translocation (sugars being the energy metabolites and building materials of plants). Fe is involved in chlorophyll formation, and the degradation and synthesis of proteins contained in the chloroplasts. Mn appears to be essential for photosynthesis, respiration and nitrogen metabolism.

B is generally immobile in the phloem. Cu, Fe, Zn, and Mn are sparingly mobile in the phloem, whereas Mo is phloem mobile.

Since Zn, Fe, and Mn are important for the normal functioning of the photosynthetic mechanism, deficiency imbalances of any one or number of these trace elements are indicated by leaf chlorosis (yellowing) to varying degrees. General chlorosis generally signifies Fe and Zn deficiency, and inter-veinal chlorosis, Fe, Zn, or Mn deficiency. New leaves show deficiency first due to these nutrients being immobile in the phloem.

In mango, trace-element spray applications made during the flowering period are effective in increasing leaf and fruit trace element concentrations. In acid soils, most of the trace elements are usually available for root uptake, whereas in alkaline soils, soil application of chelated trace elements is required due to fixation to insoluble hydroxides and oxides.

4 Nutrition Management

4.1 Guideline Information

Leaf nutrient-concentration norms should be determined with a view to orchard revenue maximization. Revenue maximization directly relates to the quantity of **good quality fruits** produced by an orchard. Fruit quality has a direct bearing on target market preference. Tree nutrient balance, as referenced from the results of leaf analysis, has been shown, by correlative analysis, to have a strong impact on fruit quality as well as on the incidence of post-harvest diseases in mango (Oosthuyse, 1997a).

Table 2 shows leaf norms (dry weight leaf concentrations) suitable for the Floridian group of mango cultivars grown for the European market (Oosthuyse, 1998a). In this group are varieties such as Tommy Atkins, Keitt, Kent, Haden and Sensation.

Table 2. *Leaf norms (dry weight concentrations) appropriate for the Floridian group of mango cultivars grown for the European market.*

N %	P %	K %	Ca %	Mg %	S %	Cu mg/kg	Fe mg/kg	Mn mg/kg	Zn mg/kg	B mg/kg	Mo mg/kg
1,0-1,2	0,1-0,2	0,8-1,2	2,0-3,3	0,2-0,3	0,1-0,2	9-18	120-190	170-450	30-75	40-80	0,3-0,6

In collecting a suitable leaf sample from an orchard block, a number of trees, well distributed within the orchard block (10 to 20 per hectare), are marked for yearly leaf sampling. Four to five leaves, located just behind the site of a fruit bearing terminal inflorescence (Figure 26), are removed from four fruit-bearing terminal shoots per tree.

Figure 26. *Leaves are sampled from a new terminal shoot bearing fruits. These shoots are those that develop after harvest each year.*

The shoots from which leaves are removed should be at shoulder height and distributed to represent each tree-quadrant. The leaves from an orchard block (usually 1 ha or smaller in area) are pooled and submitted to a laboratory for nutrient-concentration analysis.

The leaf-analysis results will indicate existing deficiency and excess imbalances. Application of nutrients in balance or deficient is made. Applications to meet the nutrient demand for the season are made for the nutrients indicated to be in balance. Added application is made in the case of the nutrients indicated to be deficient. Application of a particular nutrient is withheld if a clear excess imbalance of the nutrient is indicated. In fully-grown orchards, nutrient demand has a direct bearing on expected yield.

4.2 Nutrition Management of Mango Trees Grown in Soils Containing Clay (> 20%)

Clay particles impart soils with the ability to hold and discharge mineral nutrients into the soil solution; storage and release being controlled by chemical equilibria of the soil solution that are complex and not easily understood. Buffering of the soil solution to render sufficient nutrient supply to the root can persist for years without any fertilizer applications being made. Exchanges of cationic, as opposed to anionic, nutrient ions are far more prevalent generally, since the surfaces of clay particles are generally predominated by negatively charged entities.

Plant roots absorb dissolved mineral nutrients in the soil solution; the soil solution being the interface between storage-site and root hair (Figure 27). The dynamics of ion exchange between clay particle (or colloid), soil solution and root hair are complex. The influence of organic matter, including that of the micro-organisms themselves, further complicates the nutrient exchange dynamics occurring within the soil. Furthermore, the ability of the tree to take-up nutrients dissolved in the soil solution varies in relation to tree-health, growing environment and the climatic conditions being experienced.

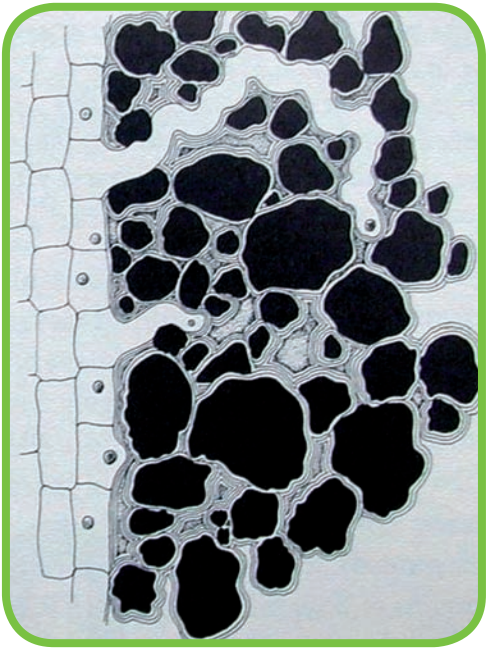

Figure 27. *Root hairs in association with the soil solution and soil particles. Roots take up water and nutrients from the soil. Only nutrients that are dissolved in the soil solution (soil water) can be utilized. Insoluble compounds cannot be accessed. However, exchanges of elements between soil solution and insoluble (solid) entities are continuous, being dictated by the chemical equilibrium state of the soil solution.*

In soils containing appreciable clay, the ability of an agronomist to predict nutrient uptake following soil application of fertilizers is limited. This is particularly stated in view of the soil having a marked ability to retain and fix nutrients, as well as to release nutrients in accordance with events occurring in the soil solution over which the agronomist can exert little control.

The approach taken in fertilizing an orchard block in this situation is empirical. Fertilizer application rates are assessed on the basis of their effect on leaf nutrient concentration changes in the particular block. With time, a good idea of the probable changes that will occur in association with particular applications made at particular stages in the yearly growth cycle can be learnt. This knowledge is used to facilitate tree nutrient-status-balance management in the long term.

In irrigated trees, differing fertilizers are placed on the soil under the trees or in the irrigation water at each of a number of growth stages. Nitrogen, calcium and phosphorous containing fertilizers are applied after harvest when new terminal shoot growth is expected. Potassium, boron, sulphur and magnesium containing fertilizers are applied during the month preceding the commencement of flowering. Potassium accumulation by the tree is particularly important at this stage. Phosphorous containing fertilizers are applied a month to six weeks after harvest, or during the early winter months. Phosphate placement in a long shallow groove made in the soil under the canopy is generally carried out. Phosphorous containing fertilizers are also spray-applied during flowering.

The micronutrients Cu, Fe, Mn, Zn, B and Mo, required by the trees in trace amounts, are generally spray applied during flowering to ensure sufficiency. Soils readily fix phosphorous and Cu, Fe, Mn and Zn (high pH soils also bind B).

The over use of ammonium-N fertilizers in clay soils should be of concern. Nitrogen storage (adsorption and fixation of NH_4^+ by the exchange complex) by the soil, rendering nitrogen availability later during the fruit growth and development period, when greatly reduced nitrogen availability is desired, is detrimental to quality, reducing ground skin colouration and increasing the incidence of internal breakdown. Where the soil NH_4^+ storage potential is significant, nitrate-N fertilization is favoured to meet the requirement for nitrogen.

4.3 Nutrition Management of Mango Trees Grown in Soils Containing Little Clay (< 10%)

Mangoes are often grown in sands, particularly in the Middle East. In this instance, the trees need to be fertilized regularly (twice or three times per week) with a fertilizer mix that, in particular, is in balance to meet the nutrient need of the fruits as they grow and develop. Knowledge concerning the fruit nutrient balance requirement for good quality is important. Sufficient fertilizer is applied to ensure that the requirements of the other growth events are met. Leaf analysis results serve, in this case, to indicate whether adjustments to a pre-determined fertigation programme are necessary.

Regular soluble fertilizer application through the irrigation system is advised. It is noteworthy that the conversion of ammonium to nitrate does not readily occur in sands due to the general absence of nitrifying bacteria.

Table 3 shows the P, K, Ca, Mg, S, Cu, Fe, Mn, Zn, B and Mo weekly requirement (grams) of superior Tommy Atkins mango fruits (of superior quality regarding the EU consumer) per gram of N required (Oosthuyse, 1999).

Table 3. *Nutrient requirement per week (in grams), per gram of N required, for developing "Tommy Atkins" fruits - from the time the fruits are 20 mm in diameter (week "0") until they reach harvest maturity (week "13").*

week	days	N g	P g	K g	Ca g	Mg g	S g	Cu mg	Fe mg	Mn mg	Zn mg	B mg	Mo mg
0	0	1	0,44	0,97	0,23	0,11	0,11	2,13	13,84	9,64	4,86	10,15	0,06
1	7	1	0,36	0,92	0,20	0,10	0,10	1,84	11,82	7,80	4,15	8,47	0,05
2	14	1	0,25	0,91	0,17	0,09	0,09	1,53	9,51	5,49	3,34	6,44	0,04
3	21	1	0,20	1,02	0,16	0,09	0,09	1,46	8,84	4,35	3,10	5,60	0,03
4	28	1	0,19	1,25	0,18	0,11	0,11	1,60	9,43	4,01	3,31	5,61	0,02
5	35	1	0,20	1,57	0,21	0,13	0,13	1,85	10,69	4,07	3,75	6,04	0,02
6	42	1	0,22	1,83	0,24	0,15	0,15	2,05	11,69	4,16	4,10	6,34	0,02
7	49	1	0,22	1,89	0,24	0,16	0,15	2,04	11,51	3,99	4,03	6,04	0,02
8	56	1	0,20	1,76	0,22	0,15	0,14	1,85	10,34	3,59	3,62	5,29	0,01
9	63	1	0,19	1,58	0,19	0,13	0,13	1,63	9,06	3,22	3,17	4,55	0,01
10	70	1	0,18	1,46	0,17	0,12	0,12	1,48	8,20	3,01	2,87	4,06	0,01
11	77	1	0,18	1,42	0,17	0,12	0,11	1,43	7,88	2,99	2,76	3,86	0,01
12	84	1	0,20	1,47	0,17	0,13	0,12	1,46	8,03	3,15	2,81	3,90	0,01
13	91	1	0,22	1,57	0,18	0,14	0,12	1,56	8,54	3,43	2,99	4,12	0,01

In fertilizing, efficiency coefficients (percentages) are used to determine the association between fertilizer amount required and the amount to be applied. These coefficients are fertilizer-type, soil-type and irrigation-method specific. For example, the efficiency coefficient of nitrate-nitrogen is greater than that for phosphate in view of the general readiness of soils to fix phosphorous, rendering it unavailable. Furthermore, the coefficients for drip-irrigated trees are generally greater than those for micro-sprinkler irrigated trees, due to the root concentrating effect at the points of water emission of drip-irrigation systems.

In general, the following equation applies: $Q_{av} = Q_s + [Q_{ap} \times F_{coeff}]$

Where, for a particular nutrient,

Q_{av} = nutrient quantity available for uptake by the tree
Q_s = available nutrient quantity the soil has in reserve (provided by the results of soil analysis)
Q_{ap} = amount of nutrient to be applied
F_{coeff} = efficiency coefficient, a percentage ranging from 0 to 100

For phosphate, F_{coeff} generally varies from 15 to 30%, whereas for nitrate, F_{coeff} variation is generally from 70 to 98%.

Where high soil levels of calcium carbonate occur, special considerations are required, since nutrient fixation reactions have a profound effect in reducing the availability (water solubility) of certain fertilizers. Applied P is quickly converted to non-available calcium-phosphates due to high levels of dissolved calcium in the soil solution. Non-chelated trace elements are quickly converted into insoluble hydroxides and oxides due to the relatively high OH^- and opposed to H^+ concentration in the soil solution.

High soil pH (resulting from high calcium carbonate levels in the soil) is a general problem in arid regions. It indirectly limits or prevents micronutrient uptake. Trees suffering from microelement deficiency are visibly unhealthy, grow poorly and clearly show deficiency symptoms (Figures 28, 29 and 30).

Figure 28. *Mango trees suffering from micro-element deficiency at Luxor in Egypt. Growth is slow, the trees are visibly unhealthy and deficiency is noted by the presence of chlorotic (yellow) small leaves.*

Figure 29. *Symptoms resulting from manganese and copper deficiency.*

Figure 30. *Iron, zinc and manganese deficiency in mango.*

4.4 Favourable Growth Stages for Spray Applied Nutrients

Nutrient uptake by soft new leaves or developing inflorescences is enhanced (Figure 31), whereas uptake is negligible by mature shoots and developing fruits. Foliar fertilizer application should be timed to match the stages when the potential for uptake is greatest. In high pH soils, spray application of micronutrients in combination with soil application of the "cationic" micronutrients in chelated form (EDTA–Cu, Mn, Zn; EDDHA–Fe), is effective in combating trace element deficiency in mango (Oosthuyse, personal observation). Fe and Zn deficiencies are noted to be difficult to correct with sprays alone.

Figure 31. *Spray applications of fertilizers when the trees are in flower is advantageous regarding uptake. The concentration and time of application should be such that burn (phytotoxicity) does not occur.*

4.5 Pre-Plant Soil Preparation

Soil samples are to be taken, and the analysis results are to be used to determine a pre-plant fertilization programme. In general, phosphate and calcium carbonate additions are necessary to correct for reduced soil phosphorous and low pH. It is absolutely imperative that phosphate be incorporated into the soil to a sufficient depth prior to planting due to its immobility in the soil. Mango trees have deep root systems; the majority of feeder roots occupying the depth of 15 to 40 cm. Sub-soiling is carried out to a depth of 80 or 100 cm. Phosphate and calcium carbonate are evenly applied to the soil surface prior to deep sub-soiling. Cross sub-soiling is considered a good practice for adequate incorporation of surface applied ameliorants.

Surface stone and rock clearing followed by levelling should precede sub-soiling and ameliorant application. After sub-soiling, further levelling and clearing can be carried out to remove rocks and debris having become exposed. Disking of the upper soil layer is often employed prior to the commencement of irrigation system installation and plant hole preparation.

5 Visual Symptoms of Certain Deficiency and Excess Imbalances

It is noteworthy that visual symptoms indicate chronic deficiencies or excesses. Generally, deficiency or excess imbalances are such that symptoms are not apparent. Leaf analysis results are essentially required to assess tree nutrient status or health.

5.1 Some Visual Micro-nutrient Deficiency Symptoms

Mango roots are relatively inefficient nutrient forages. Where the soil pH is high (> 7), trace element deficiency symptoms are readily seen in the leaves. Affected leaves are often small, ribbed and chlorotic (Figures 32 to 40).

Figure 32. *General micro-nutrient deficiency resulting from a break in the supply of micro-nutrients. Note the healthy lower leaves and deficient terminal leaves. The shoots exhibiting deficiency are smaller and chlorotic. Slight leaf deformation is apparent.*

Figure 33. *Leaf curling and stunted growth resulting from manganese and copper deficiency.*

Figure 34. *Reduced leaf size and chlorosis resulting from zinc and iron deficiency.*

Figure 35. *Stunted leaf growth and curling resulting from zinc, copper and manganese deficiency.*

Figure 36. *Ribbed, small, marginally curled, chlorotic leaves resulting from iron, zinc, copper and iron deficiency.*

Figure 37. *Leaf back-bending and ribbing resulting from manganese and copper deficiency.*

Figure 38. *General chlorosis and leaf deformation resulting from copper, iron, manganese, zinc and boron deficiency.*

Figure 39. *Terminal leaf chlorosis, necrosis and deformation resulting from general micro-element deficiency.*

Figure 40. *Leaf curling and ribbing resulting from manganese and copper deficiency.*

5.2 Some Visual Macro- and Major-Nutrient Deficiency Symptoms

Macro-nutrient deficiency symptoms are rarely observed. Symptom expression is often associated with soil-water stress (Figures 41 to 43).

Figure 41. *Yellowing (chlorosis) and marginal necrosis of leaves resulting from nitrogen and potassium deficiency.*

Figure 42. *General leaf yellowing and wilting resulting from nitrogen deficiency and prolonged soil water stress.*

Figure 43. *Internal breakdown ("jelly seed") resulting from calcium deficiency within the fruits themselves.*

5.3 Some Nutrient Excess (Toxicity) Symptoms

Mango trees are particularly susceptible to excesses of boron, sodium and chloride in the soil, readily taking-up these nutrients and subsequently showing toxicity symptoms (Figures 44 to 47).

Figure 44. *Extremely stunted new shoot development and leaf drop resulting from boron toxicity.*

Figure 45. *Leaf margin necrosis resulting from excess chloride uptake.*

Figure 46. *Inhibited tree growth resulting from excess sodium uptake.*

Figure 47. *Stunted new shoot development and leaf drop and branch die-back resulting from excess sodium and chloride uptake.*

6 Fertilization Practice and Suitable Products

6.1 Fertilizer Products Suitable for Soil Preparation

Dolomitic as opposed to calcitic lime is used to increase soil pH where the pre-plant soil concentration of magnesium is low. In rectifying soil phosphate prior to planting, single-super phosphate is the preferred phosphorous source since it also contains sulphur, a nutrient often deficient in poorer soils with a limited organic matter content.

Where soil pH levels (> 7,5) and salinity levels (EC > 2 dS/m) are high, the pre-plant inclusion of sulphur (to acidify) and gypsum (to neutralize Na) are often beneficial. Large quantities of well-composted manure (up to 100 m3 per ha) can also be applied, and incorporated to a depth of at least 80 cm, as stated for phosphate and lime (Figure 48).

Figure 48. *Where the soil pH is high (> 7,5), the incorporation of a large amount of well composted manure, the inclusion of a large amount of manure, and of gypsum and elemental sulphur is beneficial. 80 to 100 m^3 of composted manure can be incorporated per hectare. The quantities of ameliorants applied are derived from the results of soil analysis.*

6.2 Tree Fertilization: Arid Environments

In arid environments, where the soils and water are saline (ECs > 1,5 dS/m) and are rich in carbonates and bicarbonates, nitric acid enriched irrigation water (400 ml of 53% nitric acid per 1.000 l water) can facilitate soil micronutrient release and uptake. Application is made during the last hour of one or two irrigations per month, to temporarily reduce the soil-solution pH. A reduced pH renders certain nutrients, often already in the soil, available for root uptake due to them becoming soluble and entering the soil solution. Calcium and phosphate complexes and Cu, Mn, Fe and Zn oxides and hydroxides, in particular, change their state as a result of the increased concentration of H^+ in the soil solution. Nitric acid in itself is a source of nitrate, an anion for which plants have a high uptake affinity. Nitrate uptake is associated with increased uptake of the cationic plant nutrients, namely, $NH4^+$, K^+, Ca^{++}, Mg^{++}, Fe^{++}, Fe^{+++}, Cu^{++}, Mn^{++}, and Zn^{++}, due to the roots having to maintain ionic balance.

In high pH soils, urea phosphate is used as the source of phosphorous in view of its temporary acidifying effect on the soil solution.

Potassium nitrate is advised in desert soils to meet the need for K, in view of increased soil salinisation arising as a result of sulphate or chloride K application, and potassium nitrate reducing the quantity of naturally occurring chloride taken up by trees.

Microelement containing sprays should be regularly applied. Monthly or three-weekly applications during spring and summer, preferably when new shoot growth is occurring, should be made. This microelement formulation should contain Cu, Fe, Mn, Zn and Mo. Speedfol™ Amino Flower & Fruit SC is a good candidate product. The exclusion of any one of these elements is not recommended, particularly in view of leaf analysis results generally showing deficiency in all where the high soil pH condition exists due to elevated calcium carbonate content. Unless the problem of microelement deficiency is corrected, the trees will not be productive. The author does not recommend planting mango trees in soils having pH levels exceeding 8.3.

Table 4 shows an example fertigation programme for 3,5 m high mango trees growing in a calcareous, sandy soil and irrigated with drip-lines (monthly nitric acid application is not shown. N adjustment is required if nitric acid is used).

Table 4. *Fertigation programme for 3,5 m high mango trees growing in a calcareous, sandy soil, and irrigated with drip-lines (dates relevant for the northern hemisphere). Desert environment. 20 MT per ha approximated yield. Applications per week per hectare.*

growth stage	date	week	Ultrasol™ 6-6-44 kg	Ammonium Nitrate kg	Ultrasol™ Calcium kg	Ultrasol™ Magnum P44 kg	Ultrasol™ Magsul kg	Ultrasol™ Micro Rexene Cu15 g	Ultrasol™ Micro Rexene FeQ48 g	Ultrasol™ Micro Rexene Mn15 g	Ultrasol™ Micro Rexene Zn15 g	Speedfol™ B SP g	Speedfol™ Mo g
inflores. start	04-March	0	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
inflores. dev	11-March	1	5,77	3,44	1,06	0,49	1,35	16,5	225,90	41,9	31,7	38,5	0,0
inflores. dev	18-March	2	5,77	3,44	1,06	0,49	1,35	16,5	225,90	41,9	31,7	38,5	0,0
inflores. dev	25-March	3	5,77	3,44	1,06	0,49	1,35	16,5	225,90	41,9	31,7	38,5	0,0
inflores. dev	1-April	4	5,77	3,44	1,06	0,49	1,35	16,5	225,90	41,9	31,7	38,5	0,0
inflores. dev	8-April	5	11,54	6,87	2,12	0,97	2,70	32,9	451,90	83,7	63,3	77,0	0,1
full-bloom	15-April	6	11,54	6,87	2,12	0,97	2,70	32,9	451,90	83,7	63,3	77,0	0,1
full-flower	22-April	7	11,54	6,87	2,12	0,97	2,70	32,9	451,90	83,7	63,3	77,0	0,1
full-flower	29-April	8	11,54	6,87	2,12	0,97	2,70	32,9	451,90	83,7	63,3	77,0	0,1
fruit-set	6-May	9	17,32	10,31	3,19	1,46	4,05	49,4	677,80	125,6	95,0	115,5	0,1
fruit-set	13-May	10	23,09	13,74	4,25	1,95	5,40	65,9	903,80	167,5	126,6	154,0	0,1
marble fruits	20-May	11	28,86	17,18	5,31	2,43	6,75	82,3	1.129,70	209,3	158,3	192,5	0,1
goen fruits	27-May	12	34,63	20,61	6,37	2,92	8,10	98,8	1.355,60	251,2	189,9	231,0	0,2
frt growth index 0	3-June	13	40,40	24,05	7,43	3,41	9,45	115,2	1.581,60	293,1	221,6	269,5	0,2
frt growth index 1	10-June	14	46,18	27,48	8,49	3,89	10,81	131,7	1.807,50	334,9	253,2	308,0	0,2
frt growth index 2	17-June	15	51,95	30,92	9,56	4,38	12,16	148,2	2.033,50	376,8	284,9	346,4	0,3
frt growth index 3	24-June	16	57,72	34,35	10,62	4,87	13,51	164,6	2.259,40	418,7	316,6	384,9	0,3
frt growth index 4	1-July	17	51,95	30,92	9,56	4,38	12,16	148,2	2.033,50	376,8	284,9	346,4	0,3
frt growth index 5	8-July	18	46,18	27,48	8,49	3,89	10,81	131,7	1.807,50	334,9	253,2	308,0	0,2
frt growth index 6	15-July	19	40,40	24,05	7,43	3,41	9,45	115,2	1.581,60	293,1	221,6	269,5	0,2
frt growth index 7	22-July	20	34,63	20,61	6,37	2,92	8,10	98,8	1.355,60	251,2	189,9	231,0	0,2
frt growth index 8	29-July	21	28,86	17,18	5,31	2,43	6,75	82,3	1.129,70	209,3	158,3	192,5	0,1
frt growth index 9	5-August	22	23,09	13,74	4,25	1,95	5,40	65,9	903,80	167,5	126,6	154,0	0,1
frt growth index 10	12-August	23	17,32	10,31	3,19	1,46	4,05	49,4	677,80	125,6	95,0	115,5	0,1
frt growth index 11	19-August	24	17,32	10,31	3,19	1,46	4,05	49,4	677,80	125,6	95,0	115,5	0,1
full-size 12	26-August	25	17,32	10,31	3,19	1,46	4,05	49,4	677,80	125,6	95,0	115,5	0,1
maturation	2-Sept	26	11,54	6,87	2,12	0,97	2,70	32,9	451,90	83,7	63,3	77,0	0,1
maturation-harvest	9-Sept	27	11,54	6,87	2,12	0,97	2,70	32,9	451,90	83,7	63,3	77,0	0,1
maturation-harvest	16-Sept	28	11,54	6,87	2,12	0,97	2,70	32,9	451,90	83,7	63,3	77,0	0,1
maturation-harvest	23-Sept	29	11,54	6,87	2,12	0,97	2,70	32,9	451,90	83,7	63,3	77,0	0,1
maturation-harvest	30-Sept	30	11,54	6,87	2,12	0,97	2,70	32,9	451,90	83,7	63,3	77,0	0,1
maturation-harvest	7-Oct	31	5,77	3,44	1,06	0,49	1,35	16,5	225,90	41,9	31,7	38,5	0,0
maturation-harvest	14-Oct	32	5,77	3,44	1,06	0,49	1,35	16,5	225,90	41,9	31,7	38,5	0,0
maturation-harvest	21-Oct	33	5,77	3,44	1,06	0,49	1,35	16,5	225,90	41,9	31,7	38,5	0,0
maturation-harvest	28-Oct	34	5,77	3,44	1,06	0,49	1,35	16,5	225,90	41,9	31,7	38,5	0,0
winter cold	4-Nov	35	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	11-Nov	36	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	18-Nov	37	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	25-Nov	38	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	2-Dec	39	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	9-Dec	40	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	16-Dec	41	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	23-Dec	42	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	30-Dec	43	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	1-Jan	44	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	8-Jan	45	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	15-Jan	46	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
winter cold	22-Jan	47	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
flower break out	29-Jan	48	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
flower break out	5-Feb	49	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
flower break out	12-Feb	50	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
dormant bud	19-Feb	51	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
dormant bud	26-Feb	52	0,00	0,00	0,00	0,00	0,00	0,0	0,00	0,0	0,0	0,0	0,0
Totals			**727**	**433**	**134**	**61**	**170**	**2.074**	**28.469**	**5.275**	**3.989**	**4.850**	**4**

6.3 Tree Fertilization: Clay Soils Tending to be Acidic

Tree nutrient-status balance is managed with the aid of leaf norms. The rate of a fertilizer to be applied is derived empirically from historical information indicating leaf nutrient concentration changes that can be expected from various rates of fertilizer application. Soil-storage and soil-solution buffering of nutrients are significant components of the system. Hence, withholding application of certain nutrients for a year or for a number of years to reduce the extent to which an excess imbalance exists, is a consideration.

Norm determination may be based on the quality requirement of a specific target market (Figure 49). Leaf norms suiting markets that require small, poorly coloured, but very sweet fruits, will differ from those suiting markets that require well-coloured, large fruits free of internal breakdown.

Figure 49. *Good quality fruits are generally considered to be those that are free of disease, show complete skin ground colouration from green to yellow, and are free of internal break-down, by consumers in the European Union.*

Table 5 presents a fertilization programme for mango trees growing in soils tending to be acidic and containing appreciable clay (clay imparts soils with the ability to store and release nutrients into the soil solution from where root nutrient uptake takes place).

Table 5. *Fertilization programme for mango trees growing in soils tending to be acidic and containing appreciable clay (> 20%) (amounts in grams per tree or spray rate in ml per 100 l water; adjustments can be made based on the results of leaf analysis).*

Stage of yearly cycle	Fertilizer	Small tree 1 – 2,5 m high	Medium tree 2,6 – 3,5 m high	Large tree 3,6 – 6 m high
Post-harvest	Soil-Ammonium nitrate Soil-Qrop™ Calcium Soil-Qrop™ MAP	100 g 320 g 150 g	200 g 650 g 300 g	300 g 960 g 450 g
Month prior to flowering	Soil-Qrop™ SOP Qrop Boronat™ 32 Soil-Ultrasol™ Magsul	375 g 30 g 100 g	750 g 50 g 200 g	1.130 g 70 g 300 g
During flowering	*Spray-Speedfol™ Amino Flower & Fruit SC (x 2 sprays, first anthesis, second full-bloom)	300 ml	300 ml	300 ml
	Spray- Ultrasol™ MKP (x 2 sprays, first anthesis, second full-bloom)	1.000 g	1.000 g	1.000 g
	Spray- Ultrasol™ K (x 2 sprays, first anthesis, second full-bloom)	2.000 g	2.000 g	2.000 g
Start of fruit growth and development	Soil-Calcium sulphate	300 g	500 g	800 g

*Spraying should not be carried out during the heat of the day.

6.4 Preferred Fertilizers for Acidic and Alkaline Soils

Certain fertilizers are preferred for mango (Table 6 and 7). These preferences are based on the experiences of the author.

Table 6. *Preferred sources of the macro- and major-nutrients in mango – soil application after planting.*

Nutrient	Low pH - soil/water	High pH - soil/water	Comments
N	Ammonium nitrate	Ammonium sulphate Ammonium nitrate	Ammonium sulphate is most acidifying.
P	Mono-potassium phosphate Mono-ammonium phosphate	Phosphoric acid Urea phosphate	A high degree of solubility is required to ensure maximal macro-pore penetration. Acidifying phosphates are beneficial in high pH soils.
K	Potassium nitrate Potassium sulphate	Potassium nitrate	Nitrate uptake reduces the effect of chloride and favours cationic nutrient uptake.
Ca	Calcium nitrate	Calcium nitrate	As for K.
Mg	Magnesium sulphate	Magnesium sulphate	Magnesium sulphate is suitable for high and low pH soils in view of Mg being required in far lesser amounts than N and K.
S			S is present in certain of the above fertilizers.

Table 7. *Preferred sources of micro-nutrients – spray or soil application after planting.*

Nutrient	Foliar application	Soil application	Comments
Cu	Amino acid chelate Gluconate complex Lignosulphonate complex Citric acid complex Suspension concentrate EDTA chelate	EDTA-Cu	Foliar rectification is possible. Do not spray apply with metal based pesticides or fungicides.
Fe	As for Cu	EDTA (low pH), DTPA-Fe (neutral pH levels) or EDDHA-Fe, EDDHMA-Fe (pH levels > 7,5)	Success in rectifying Fe deficiency with sprays is limited. Do not mix with metal based pesticides or fungicides.
Mn	As for Cu	EDTA-Mn	Foliar rectification is possible. Do not mix with metal based pesticides or fungicides.
Zn	As for Cu Zinc nitrate	EDTA-Zn	Foliar rectification is possible. Zinc nitrate is generally not compatible with other spray-products. Do not mix with metal based pesticides or fungicides.
B	Sodium borate Boric acid	Calcium-sodium borate Sodium borate Boric acid	B should preferably be applied to the soil due to its immobility in the phloem in most crop plants.
Mo	Sodium molybdate Ammonium molybdate		Mo fertilizer products are most effective in meeting the need for Mo when they are spray applied.

6.5 General Foliar Fertilization Practices

6.5.1 Increasing Mango Flowering Intensity in Tropical, Wet or Dry Regions

Potassium nitrate, spray-applied before flowering, increases flowering intensity in certain climatic zones and varieties (Maas, 1989; Sergent and Leal, 1989). The effect has been ascribed to an increased number of terminal buds developing during the period when environmental conditions are optimally inductive for flowering (Davenport and Nunez-Elisea, 1997). Spray application, at 2 or 4% (w/v) every 14 days, commencing six weeks before the start of flowering, is practiced. Potassium nitrate application is made in conjunction with that of paclobutrazol (Cultar) to enhance the flowering response (Mossak, 1996). Paclobutrazol is applied to the soil under the trees five months prior to the flowering period.

6.5.2 Increasing Fruit Retention by Reducing Post-Flower Fruit-Drop

Potassium nitrate spraying during flowering is effective in reducing the post-flower drop of seeded fruits, and thereby, increases yield (Oosthuyse, 1993a, 1993b). Two 2% (w/v) applications are generally made, the first at the start of flower opening (anthesis), and the second, when the inflorescences are in full-bloom.

6.5.3 Controlling Powdery Mildew Colonization of the Inflorescences

Mono potassium phosphate (MKP) sprays at 1% (w/v), during the period of inflorescence development, are effective in controlling powdery mildew (*Oidium mangiferae*), and increasing the tree's phosphorous and potassium status (Oosthuyse, 1998b, Oosthuyse, unpublished data).

Spraying is particularly significant in the situation where the soil fixes phosphate readily (i.e. in high pH soils containing calcium carbonate or in acidic soils), rendering it unavailable for uptake by the tree, or where soil-P is deficient (to replenish soil-P in an established orchard is exceedingly difficult).

7 Some Pertinent Research Results

7.1 Research Attesting to the Importance of Nutrient Balance

Excess nitrogen, in relation to calcium and potassium, is often associated with poor ground skin colouration and a high incidence of physiological disorders (internal breakdown, mostly) (Oosthuyse, 1997a) (Figures 50 and 51).

Figure 50. *Stem-end cavity formation considered to result from reduced fruit calcium levels relative to those of nitrogen and potassium, as well as to water status fluctuations occurring during the fruit growth and development period. Internal cavities are often associated with internal breakdown.*

Figure 51. *Jelly-seed (internal breakdown) resulting from nutrient imbalance in the fruits. High nitrogen relative to potassium and calcium is generally associated with the development of internal-breakdown-type physiological disorders.*

Spray application of calcium has been found to increase bacterial black spot (*Xanthomonas campestris*) incidence in Sensation mango (Oosthuyse, 1997b). This presumably occurs when a calcium excess imbalance already exists.

Both deficiency and excess nutrient imbalances negatively impact on productivity, this having been shown in carrying out multivariate statistical analyses (Oosthuyse, 1997a).

7.2 Increased Fruit Retention and Yield Resulting From Spray Application of Potassium Nitrate

Oosthuyse (1993a) reported an increase in fruit retention and tree yield after spraying flowering Tommy Atkins mango trees with potassium nitrate. Figures 52 and 53 show the effect in an additional study (Oosthuyse, 1994, unpublished) where the varieties Tommy Atkins, Kent and Heidi were included. Similar increases were found in the varieties Kent and Heidi. In the latter varieties, best results were found when two 2% sprays were made, whereas in Tommy Atkins, one 4% spray resulted in the greatest increase in fruit retention and yield. 2% KNO_3 application at the commencement of anthesis (flower opening), followed by 2% KNO_3 application when the trees are in full-bloom, is generally recommended.

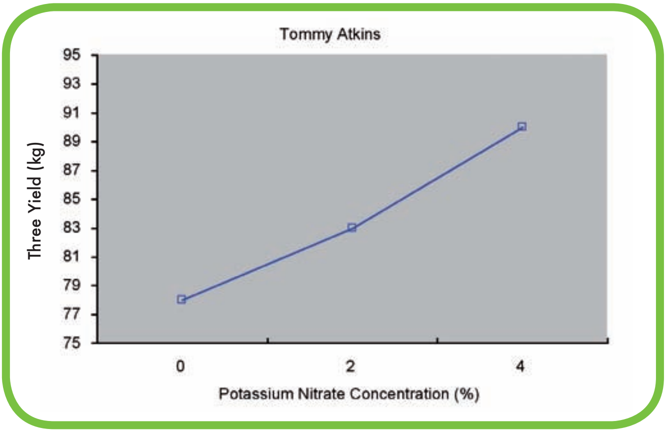

Figure 52. *Increases in tree yield in relation to the concentration of potassium nitrate sprayed on Tommy Atkins mango trees when in full-bloom (statistically significant linear trend, P < 0,05).*

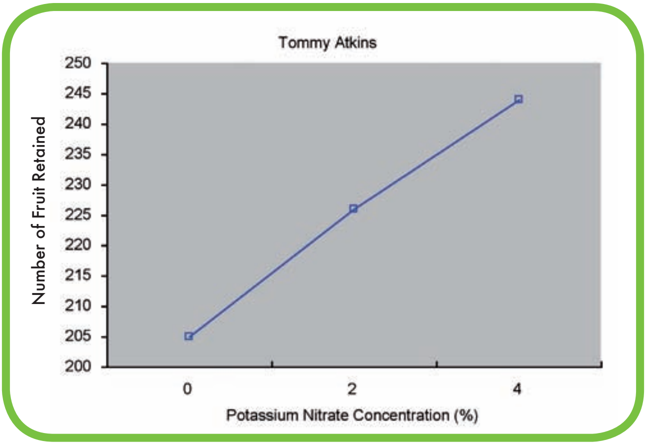

Figure 53. *Increases in number of fruit retained in relation to the concentration of potassium nitrate sprayed on Tommy Atkins mango trees when in full-bloom (statistically significant linear trend, P < 0,05).*

7.3 Powdery Mildew Control Resulting from Spray Application of Mono-Potassium Phosphate

Oosthuyse (1998b) spray-applied mono-potassium phosphate (KH_2PO_4 or MKP), a potassium-phosphate fertilizer, to flowering Kent and Tommy Atkins mango trees, either alone or with conventionally used curative fungicides [Punch C (carbendazim and fluziloazol), Benlate (bonomyl), Folicur (tebuconizole), Omega (prochloraz), or wetable sulphur], generally at quarter strength. Unsprayed trees served as controls, and certain trees were sprayed with Bayfidan at full strength.

In Kent, the fungicide/MKP mixes were almost as effective as Bayfidan at full strength in reducing tree percentage of diseased inflorescences (Figures 54 and 55). It was found that MKP applied alone was less effective than Bayfidan in this regard. In Tommy Atkins, however, the fungicide/MKP mixes were as effective as Bayfidan at full strength in reducing tree percentage of diseased inflorescences (Figures 56 and 57). MKP applied alone was apparently slightly less effective than Bayfidan in this regard. In Kent and Tommy Atkins, the extent of mildew inflorescence colonization was reduced by all of the sprays applied. In Kent, the reduction was most marked following Bayfidan application. The results were clearly seen to show that MKP is effective in retarding the development of powdery mildew on mango inflorescences, and can thus be used to reduce the cost of powdery mildew control in mango.

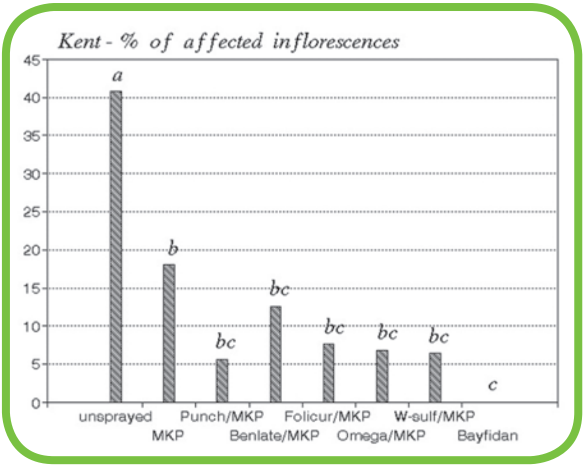

Figure 54. *Percentage of Kent inflorescences showing signs of powdery mildew (Oidium mangiferae) in relation to spray treatment. Bars headed by differing letters indicate mean separation according to the 5% LSD criterion.*

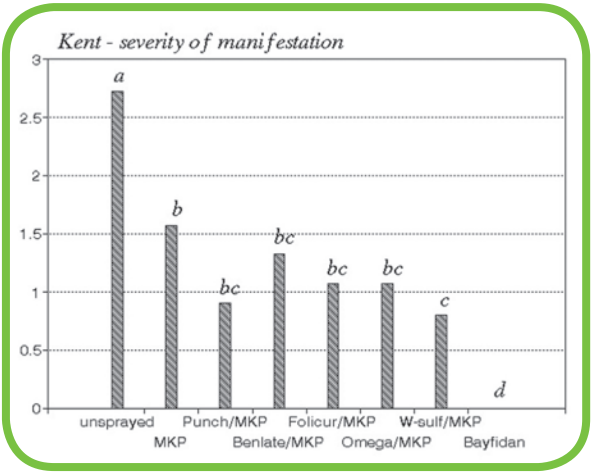

Figure 55. *Severity of inflorescence powdery-mildew colonization in relation to spray treatment in Kent. Bars headed by differing letters indicate mean separation according to 5% the LSD criterion.*

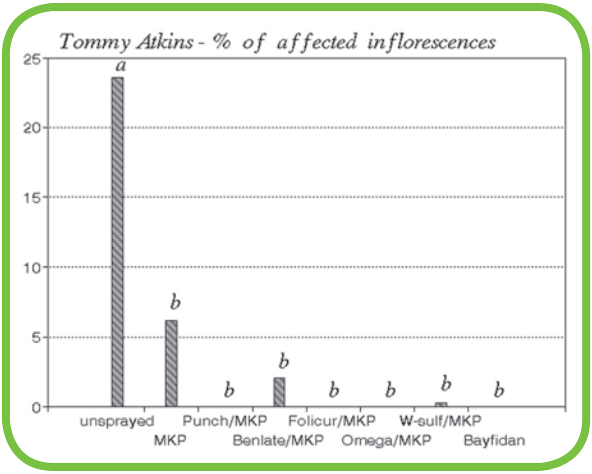

Figure 56. *Percentage of Tommy Atkins inflorescences showing signs of powdery mildew in relation to spray treatment. Bars headed by differing letters indicate mean separation according to 5% the LSD criterion.*

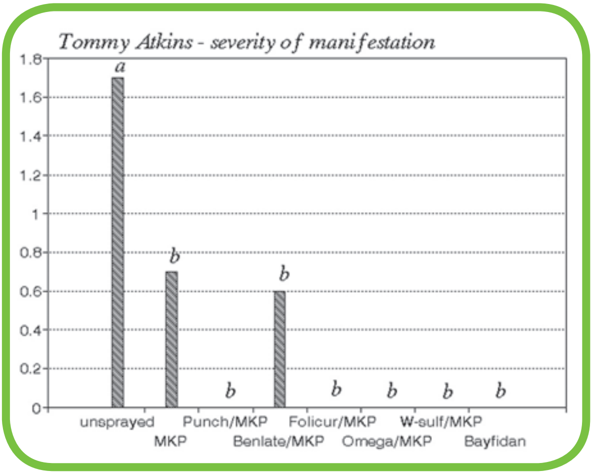

Figure 57. *Severity of inflorescence powdery-mildew colonization in relation to spray treatment in Tommy Atkins. Bars headed by differing letters indicate mean separation according to 5% the LSD criterion.*

7.4 General Research Findings

Many other responses have been documented concerning specific fertilizer applications to mango trees. Most show benefits where the relevant deficiency imbalances existed prior to treatment, or the absence of an effect or a negative effect, where the relevant excess imbalances were in place before treatment.

Ultrasol™

Qrop™

Speedfol™
Foliar Certified Solutions

8 Literature

Davenport, T.L. and Nunez-Elisea, R. 1997. Reproductive physiology. In: The mango: Botany, production and uses. Litz, R.E. ed. CAB International, pp. 69-146.

Maas, E.F. 1989. In Nicaragua; Potassium nitrate foliar spray induces bloom in mango orchard. Better Crops International 5:4-5.

Mossak, I.I. 1996. A study of early flowering in mango, Part 1. Tropical Fruits Newsletter 21:6-8.

Nakasone, H.Y. and Paull, R.E. 1998. Mango. In: Tropical Fruits, CAB International, pp. 208-269.

Oosthuyse, S.A. 1991. Stages of development of the mango panicle. S.A. Mango Growers' Assoc. Yearbook 11:59-61.

Oosthuyse, S.A. 1993a. Effect of spray application of KNO_3, urea and growth regulators on the yield of Tommy Atkins mango. S.A. Mango Growers' Assoc.Yearbook 13:58-62.

Oosthuyse, S.A. 1993b. Research on mango aimed at increasing orchard productivity and export fruit quality. S.A. Mango Growers' Assoc.Yearbook 13:40-44.

Oosthuyse, S.A. 1996. Changes in mango fruit quality in relation to stage of maturation. Research project, Merensky Holdings, South Africa, 1996.

Oosthuyse, S.A. 1997a. Relationship between leaf nutrient concentrations and cropping or fruit quality in mango. S.A. Mango Growers' Assoc. Yearbook 17:1-5.

Oosthuyse, S.A. 1997b. The effect of calcium and magnesium chelate sprays at flowering on fruit quality and physiological disorders in mango. S.A. Mango Growers' Assoc. Yearbook 17:29-32.

Oosthuyse, S.A. 1998a. Determination of optimum leaf nutrient concentration norms for a number of mango cultivars: Year I. S.A. Mango Growers' Assoc. Yearbook 18:1-5.

Oosthuyse, S.A. 1998b. Cost reduction of powdery mildew control in mango with mono potassium phosphate. S.A. Mango Grower's Assoc. Yearbook 18:40 42.

Oosthuyse, S.A. 1999. Weekly nutrient content changes of developing Tommy Atkins mangoes until harvest maturation. Research project, Agrofert Fertilizers, South Africa, 1999.

SQM S.A.
Los Militares 4290
Las Condes, Santiago, Chile
Tel: (56 2) 425 2000
Fax: (56 2) 425 2416
E-mail: spn-chile@sqm.com

Soquimich Comercial S.A.
Los Militares 4290, Piso 3
Las Condes, Santiago, Chile
Tel: (56 2) 425 2525
Fax: (56 2) 425 2266
E-mail: servicioalcliente@sqm.com

SQM Brasil
Alameda Tocantis 75, Sexto Andar
Alphaville, Barueri, CEP, 06455-020
Sao Paulo, Brasil
Tel: (55 11) 413 37210
Fax: (55 11) 413 37205
E-mail: spn-brasil@sqm.com

SQM Ecuador S.A.
Avda. Juan Tanca Marengo y Avda. José
Orrantía, Edificio Executive Center, Piso 3
Office 307, Guayaquil, Ecuador
Tel: - Fax: (593 4) 269 0639
E-mail: spn-ecuador@sqm.com

SQM Perú S.A.
Avda. Camino Real N° 348
Oficina 701, Torre el Pilar
San Isidro, Lima, Perú
Tel: (511) 611 2121
Fax: (511) 611 2122
E-mail: servicioclienteperu@sqm.com

SQM Comercial de México S.A. de C.V.
Industria Eléctrica s/n Lote 30, Manzana A
Parque Industrial Bugambilias C.P. 45645
Tlajomulco de Zúñiga, Jalisco, México
Tel: (52 33) 354 01100
Fax: (52 33) 354 01101
E-mail: infomexico@sqm.com.mx

SQM North America
3101 Towercreek Parkway
Suite 450, Atlanta, GA 30339 USA
Tel: (1 770) 916 9400
Fax: (1 770) 916 9401
E-mail: spn-northamerica@sqm.com

SQM Asia Pacific
Sint Pietersvliet 7, bus 8
2000 Antwerpen - Belgium
Tel: (32 3) 203 9700/20
Fax: (32 3) 203 9772
E-mail: spn-asia@sqm.com

SQM Europe, Middle East & Africa
Sint Pietersvliet 7, bus 8
2000 Antwerpen - Belgium
Tel: (32 3) 203 9700/20
Fax: (32 3) 203 9772
E-mail: spn-emea@sqm.com

www.sqm.com