Avocado fertilizing principles
E. Joubert 2016

Avocado fruit quality and orchard performance can be coupled with nutrient availability reflected in the fruit, leaves and soil. A good fertiliser program should, in conjunction with low environmental, pest- and disease stress, minimize excessive flower drop and alternate bearing retain tree health and maximize fruit set, size and quality. Scientific trials and practical experience resulted in the useful management tools that have been summarized and compiled in this article.

Crop removal figures

A good starting point for a good fertiliser program is the crop removal figures for the past season and the crop estimates for the following season. In Table 1 the seasonal macro element withdrawal on three different types of soil for Hass are given as kg per ton yield or g/cm trunk circumference. It is important to note that the crop removal figures should be studied with soil and leaf analyses results, especially in very fertile soils, so that deficiencies and excesses of elements are taken into consideration when determining whether additional nutritional applications are required. Growers with fertile soils (> 24% clay) should do organic matter analyses to estimate Nitrogen (N) mineralization and the total N requirement can be reduced by up to 20% in areas that experience thunderstorms during the summer months (Snijder & Stassen 2000).

Table 1 Macro elements withdrawn from the orchard system in kg per ton yield for Hass. The values in brackets are the equivalent gram nutrient withdrawn per cm trunk circumference (Snijder & Stassen 2000).

<table>
<thead>
<tr>
<th>Soil clay content</th>
<th>Nitrogen (N)</th>
<th>Phosphorous (P)</th>
<th>Potassium (K)</th>
<th>Calcium (Ca)</th>
<th>Magnesium (Mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy soil</td>
<td>0-12 %</td>
<td>7.1 (5.3)</td>
<td>1.2 (0.9)</td>
<td>10.2 (7.6)</td>
<td>3.3 (2.5)</td>
</tr>
<tr>
<td>Medium potential soil</td>
<td>13-24 %</td>
<td>5.7 (4.2)</td>
<td>1.0 (0.7)</td>
<td>8.2 (6.1)</td>
<td>2.6 (2.0)</td>
</tr>
<tr>
<td>High potential soil</td>
<td>&gt; 24 %</td>
<td>4.5 (3.4)</td>
<td>0.8 (0.6)</td>
<td>65 (4.9)</td>
<td>2.1 (1.6)</td>
</tr>
</tbody>
</table>

Basic avocado nutrient requirements

In Table 2 the basic requirement of N, P and K per year per avocado tree age is summarised. Young avocado trees (up to 18 months old) can be fertilised with 20 g SAAGA mix per tree per month. The application can be doubled with each flush up to a maximum of 100 g SAAGA mix per tree per month. The SAAGA mix is a dry mix of: 3 parts KAN, 2 parts MAP and 1 part KNO₃. Table 3 summarise the function of each fertiliser element together with application recommendations. Note that the exact amounts of fertiliser will change according to cultivar type, leaf and soil analysis results, tree age and previous years’ yield. For example, due to a higher rate of respiration, and a longer hanging season, Hass has a higher fertiliser requirement in comparison to Fuerte (Snijder & Stassen 2000). Refer to the quarterly management guidelines for more specific recommendations with regard fertilizer application timing.
Table 2 Guideline for the quantity of fertilizer (in grams) per year per avocado tree age required (Stones 2009, Abercrombie 2011).

<table>
<thead>
<tr>
<th>Drip area diameter (m)</th>
<th>Tree age</th>
<th>Nitrogen (N)</th>
<th>E.g. LAN (28% N)</th>
<th>Phosphorous (P)</th>
<th>E.g. Superphosphate (11.3% P)</th>
<th>Potassium (K)</th>
<th>E.g. K₂SO₄ (40% K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1</td>
<td>42</td>
<td>150</td>
<td>21</td>
<td>200</td>
<td>75</td>
<td>190</td>
</tr>
<tr>
<td>1.5</td>
<td>2</td>
<td>84</td>
<td>300</td>
<td>42</td>
<td>400</td>
<td>150</td>
<td>375</td>
</tr>
<tr>
<td>2.5</td>
<td>3</td>
<td>126</td>
<td>450</td>
<td>63</td>
<td>600</td>
<td>225</td>
<td>560</td>
</tr>
<tr>
<td>4.5</td>
<td>4-5</td>
<td>168</td>
<td>600</td>
<td>95</td>
<td>900</td>
<td>300</td>
<td>750</td>
</tr>
<tr>
<td>6</td>
<td>6-7</td>
<td>224</td>
<td>800</td>
<td>126</td>
<td>1200</td>
<td>600</td>
<td>1000</td>
</tr>
<tr>
<td>7.5</td>
<td>8-9</td>
<td>280</td>
<td>1000</td>
<td>158</td>
<td>1500</td>
<td>500</td>
<td>1250</td>
</tr>
<tr>
<td>9</td>
<td>10-12</td>
<td>336</td>
<td>1200</td>
<td>189</td>
<td>1800</td>
<td>600</td>
<td>1500</td>
</tr>
<tr>
<td>10 +</td>
<td>12 +</td>
<td>420</td>
<td>1500</td>
<td>189</td>
<td>1800</td>
<td>750</td>
<td>1875</td>
</tr>
</tbody>
</table>

References


Table 3 Summary table of the nutrients important for avocado production. The function of each nutrient, requirement, norm, and examples of application rates, application timing and more about the deficiency symptoms are given.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Function / Required for:</th>
<th>Norm</th>
<th>Nutrient application examples</th>
<th>Essential time in phenology</th>
<th>Deficiency symptom</th>
<th>Cause of deficiency</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level of soil acidity (pH)</strong></td>
<td>Optimum pH enhances cation exchange capacity in soil.</td>
<td>Subsoil pH (H₂O/KCl) = 5.8 - 6.5 / 4.8 – 5.5.</td>
<td>Pre-plant: Use calcitic lime if the Ca:Mg ratio &lt; 2. Regular maintenance: lime applications can be done every 1-2 years at 1-2 ton/ha to counteract re-acidification of the soil by acidifying fertilisers, rainfall or irrigation.</td>
<td>Pre-plant or regular maintenance.</td>
<td>High rainfall naturally lead to soil acidification.</td>
<td>Fouché 1981; Du Plessis &amp; Koen 1987</td>
<td></td>
</tr>
<tr>
<td><strong>Macronutrients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium (Al)</td>
<td>High exchangeable Al content in the soil correlates with a low soil pH, leaching of essential plant nutrients such as Ca, Mg, K and low yield.</td>
<td>Topsoil exchangeable Al content &lt; 20 mg/kg.</td>
<td>Timely lime applications according to pre-plant soil analysis.</td>
<td>Pre-plant or regular maintenance.</td>
<td>Light, sandy, acidic soil (low pH). High Na, Mg or Al levels in soil. Low soil moisture or drought. Uptake affected in decreasing order by the presence of K, ammonium, Mg &amp; Na.</td>
<td>Fouché 1981; Du Plessis &amp; Koen 1987</td>
<td></td>
</tr>
<tr>
<td>Calcium (Ca²⁺)</td>
<td>Ca is important for cell division and cell elongation. Important for the normal function of cell membranes. Permeability of cell membranes. Ca is an important building block of cell walls and help reduce internal quality problems. Reduce the incidence of disorders at growing points in synergism with B.</td>
<td>Leaf: Ca = 1.2 - 2.0 %, Optimal B : Ca ratio is 1 : 0.03 at 3-4 true leaf stage for proper growth. Optimal Mg : Ca ratio is 1 : 4. Optimal K : Ca ratio is 1 : 0.75.</td>
<td>Foliar application: Use CaNO₃ at a rate of 100-300 kg/ha split into 2-4 applications over 6-8 weeks.</td>
<td>Rectify Ca deficiencies as early as possible in the season. Early spring flush, flowering and fruit set (August - September). Young leaves show leaf tip necrosis (leaf burn). Death of young buds. Short storage life of fruit. Low Ca levels correlates with high grey pulp incidence in Fuerte and Pinkerton.</td>
<td>Light, sandy, acidic soil (low pH). High Na, Mg or Al levels in soil. Low soil moisture or drought. Uptake affected in decreasing order by the presence of K, ammonium, Mg &amp; Na.</td>
<td>Koen et al. 1990; Abercrombie 2011; Crous &amp; Retief 2010; Agrichem</td>
<td></td>
</tr>
<tr>
<td>Function / Required for:</td>
<td>Norm</td>
<td>Nutrient application examples</td>
<td>Essential time in phenology</td>
<td>Deficiency symptom</td>
<td>Cause of deficiency</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
<td>-------------------------------</td>
<td>----------------------------</td>
<td>-------------------</td>
<td>---------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Fruit: Ca &gt; 0.15 % (Nov) and &gt; 0.05 % (Feb). Ca:N level &gt; 0.1 (Nov) and ± 0.1 (Feb).</td>
<td>0.5 &amp; &lt; 1.5 respectively.</td>
<td>Limited downward movement. Movement to meristematic tissue limited by high humidity.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium (Mg$^{2+}$)</td>
<td>Low Mg levels correlates with high grey pulp incidence in Fuerte. Mg is important during photosynthesis, forming chlorophyll molecules, cell division and as an energy source in the plant. Mg will synthesise proteins and metabolize P and N.</td>
<td>Leaf: Mg = 0.7 - 1.0 %. Mg : Ca ratio of 1 : 4. Mg : K ratio of 1 : 3. Topsoil: Ca/ Mg ratio = 2.5 - 5.0 mg/kg. Soil: Mg = 200 - 400 ppm.</td>
<td>Foliar application: Chelated Mg (5 % Mg) can be applied at a rate of 4 - 8 L/ha. A suspension Mg (30 % Mg) can be applied at a rate of 9 - 12 L/ha on the spring and summer flushes. Cal-Mag-Nitrate can be applied at 5-10 g/m$^2$ where Mg and Ca deficiencies are observed. Soil application: Dolomitic lime can be used as a source of Mg in the soil.</td>
<td>Early spring flush, flowering and fruit set (August - September). Mg is mobile in phloem. Mg can be transported from older leaves to shoot apex. Mg moves via mass flow to avocado roots.</td>
<td>Older leaves develop interveinal chlorosis. Yellow colour moves from tip of leaf toward the midrib of leaf. Base of leaf often stays green.</td>
<td>Acidic soils (low pH). In acidic soils, Al competes with Mg for root uptake sites. Sandy, lightly structured soil. High K content in the soil. Some cultivars / rootstocks show poor Mg uptake. Wet, cool weather. Uptake affected in decreasing order by the presence of K, ammonium, Ca &amp; Na.</td>
<td>Koen et al. 1990; Abercrombie 2011; Crous &amp; Retief 2010; Agrichem</td>
</tr>
<tr>
<td><strong>Function / Required for:</strong></td>
<td><strong>Norm</strong></td>
<td><strong>Nutrient application examples</strong></td>
<td><strong>Essential time in phenology</strong></td>
<td><strong>Deficiency symptom</strong></td>
<td><strong>Cause of deficiency</strong></td>
<td><strong>Reference</strong></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Phosphorous (P)</td>
<td>Development &amp; stimulation of root growth of young trees. Phosphate is very important in the plant’s metabolic process (energy transfer). Cell division. Photosynthesis. Sugar and starch formation. Movement of carbohydrates.</td>
<td>Leaf: 0.15 - 0.2 %. P : N ratio of 1 : 15 during summer leaf flush. Topsoil: 8 - 27 mg/kg (Resin method), 14 - 46 mg/kg (Ambic method), 18 - 60 mg/kg (Bray 1 method).</td>
<td><strong>Soil application:</strong> Use Superphosphate (10%) at 50 g/m² drip area or MAP (10-20 g/m² drip area). Apply to individual yellow looking trees to rectify tree differences in the orchard. <strong>Foliar application:</strong> Apply a NPK mix of 14 % N, 12 % P and 3 % K at a rate of 10 - 30 L/ha in a 1.5 ratio mixed with water.</td>
<td>Root growth and root flush (October - December and March - April). Mobile in xylem and phloem. Phosphorous is converted to an organic form within minutes of uptake and quickly metabolized. Inorganic parts of the applied P (85 - 90 %) is stored in vacuoles as orthophosphate. Mg activated kinase enzymes and trigger many P energy transfer reactions.</td>
<td>Stunted growth. Small leaves. Bronze colour in new growth. Bronzing has been observed on Lamb Hass and the deficiency was plausibly rectified with a foliar application of MAP.</td>
<td>Extremes in soil pH. Low organic matter. Plants with poor root structures. P retentive soils. High Fe content in soil. Cool, wet weather. Low B levels reduce the ability of P to transfer energy in the plant and may half the capacity of the plant to absorb P. Low Zn levels results in unregulated P uptake, may cause excessive / toxic levels of P (similar visual symptoms as Zn deficiency). Al combines with P in the intercellular areas of the root tips and decrease P translocation of</td>
<td>Abercrombie 2011; Sheard 2009; Agrichem</td>
</tr>
<tr>
<td>Function / Required for:</td>
<td>Norm</td>
<td>Nutrient application examples</td>
<td>Essential time in phenology</td>
<td>Deficiency symptom</td>
<td>Cause of deficiency</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
<td>-------------------------------</td>
<td>-----------------------------</td>
<td>-------------------</td>
<td>----------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Nitrogen (N⁺)</td>
<td></td>
<td>Fuerte leaf: 1.7 - 1.9 %, Hass leaf: 2.2 - 2.3 %</td>
<td>Nitro-humus (323 at 15 - 20 L/ha), LAN (28% N), NPK combinations, MAP, CaNO₃ or KNO₃ can be used as sources of N. Fertilizer should be spread evenly 20 cm from the stem to about 50 cm outside the drip area of the tree and followed by light, controlled irrigation.</td>
<td>Young trees: 4-6 applications during active growth period (August - April). Bearing trees: 3-4 applications to result in 15-30% of the annual N requirement about 4-6 weeks before full flower or early fruit set, 10-25% with spring vegetative growth, 30-40% with the summer vegetative growth and 20-30% after harvest. Nitrate is mobile. Older leaves turn pale green to yellow first. Veins lighter in colour than the rest of the leaf. Affected leaf edges may roll upward. Severe deficiency tip burn and leaf fall may occur. High N levels an low Ca levels result in grey pulp occurrence in Pinkerton.</td>
<td>Sandy, lightly structured soil. Extremes of pH. Poor levels of organic matter. High rainfall or heavy irrigation (leaching). Large quantity of crop residue, need N to decompose. Crops with rapid growth habit. A deficiency of Mo will decrease N use because enzyme nitrate reductase is dependent on Mo. Mg will</td>
<td>Abercrombie 2011; Sheard 2009; Agrichem</td>
<td></td>
</tr>
<tr>
<td>Function / Required for:</td>
<td>Norm</td>
<td>Nutrient application examples</td>
<td>Essential time in phenology</td>
<td>Deficiency symptom</td>
<td>Cause of deficiency</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
<td>------------------------------</td>
<td>-----------------------------</td>
<td>-------------------</td>
<td>---------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td><strong>Potassium (K⁺)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sheard 2009</td>
<td></td>
</tr>
<tr>
<td>Important role in cell division, transpiration, stress reduction, fruit size and disease resistance. Stomatal function and turgor pressure. Synthesis of proteins. Enzyme activator &amp; coenzyme function. Na may replace K in several essential roles.</td>
<td><strong>Leaf:</strong> 0.75 - 1.15 %. K : N ratio of 1 : 1.75 for strong, firm growth.  K : Ca ratio of 1 : 0.75 for summer flush leaf test.  <strong>Soil:</strong> 70 (sandy soil) - 250 (clay soil) ppm.  <strong>Fruit:</strong> &gt; 1.5 % (Nov) and &gt; 1.8 % (Feb).  Fruit N:K ratio &gt; 1.0 (Nov) and &lt; 0.5 (Feb).  <strong>Foliar application:</strong> Liquid potassium (30 % K) can be applied at a rate of 10 - 12 L/ha.  <strong>Ground application:</strong> Apply KSO₄ or KNO₃ at 10 g/m² of ground area covered by tree canopy. Only use KNO₃ if leaf N levels in Greenskins &lt; 1.9 or &lt; 2.0 in Hass.  KCl is not a recommended source of K because the chloride content can result in leaf burn and are detrimental for organic and biological subsistence in the soil.</td>
<td>Supply 30 % 4-6 weeks before full flower, 40 % during summer vegetative growth and 30% after harvest.  K uptake by roots are attributed to small hydrophobic molecules that increase ion permeability through membranes (ionophores) which aid diffusion inside root cells. Most cellular membranes are highly permeable to K. Upward movement via</td>
<td>Intervenial chlorosis of leaves or light brown spots on leaves. Small, narrow leaves.</td>
<td>Acidic soils (low pH). Sandy, lightly structured soil (leaching). High Mg content in the soil. Low K soils have limited K uptake. Drought. Ammonium depress the uptake of K.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function / Required for:</td>
<td>Norm</td>
<td>Nutrient application examples</td>
<td>Essential time in phenology</td>
<td>Deficiency symptom</td>
<td>Cause of deficiency</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td><strong>Micronutrients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Boron (B)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Important for good flower formation and fruit set. Essential for Ca transport and normal development of plant tissues at growing tips of shoots, branching, flowers, fruit and roots (apical meristems). Important for metabolism of carbohydrates (incl. sugars and their derivatives and polysaccharides such as starch &amp; cellulose). Synthesis of nucleic acids. Especially important during pollination, pollen tube growth and early fruit set. Reduce the incidence of disorders at growing points in synergism with Ca.</td>
<td>Leaf: 50 - 80 ppm. Optimal B : Ca ratio is 1 : 0.03 at 3-4 true leaf stage for proper growth. Soil: 0.25 (sandy soil) - 12 (clay soil) ppm.</td>
<td>Foliar application: Apply 2-3 sprays of 100 g/100L (3 - 4 g/m²) Solubor (± 21 % B) or 3 - 5 L/ha Ammonium Borate (10 - 15 % B, 4.1 - 6.3 % N) as a medium cover spray (&gt; 1000 L water/ha) during the main foliar flushes. Note that B uptake is limited if application does not correspond with foliar flushes during which time soil applications of B are strongly advised. Soil application: 10 g/m² Boronat (10 % B) spread evenly under tree canopy. Note that lower rates of B should be applied in sandy soil and for Pinkerton. Foliar application during spring on actively growing leaves or during the main root flush on the soil. Mobility is relatively low in the plant. The sugar borate complex form of B is mobile in xylem. Mobility in phloem is limited. May be lost through water exudation from plant.</td>
<td>xylem toward new growth. Redistribution from old to new growth is common. Fruit small &amp; misshapen. Fruit to stem joint is skew and twisted. Abortion of fruit. Chlorosis of leaf tips and margins in young leaves. Death of young buds and new growing shoots. Shoot tip death result in knob on shoot.</td>
<td>Light, sandy soil. Too much N. Too much Ca. Cold / wet weather. Low soil moisture (drought).</td>
<td>Bard &amp; Wolstenholme 1997; Sheard 2009; Agrichem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>Function / Required for:</td>
<td>Nutrient application examples</td>
<td>Essential time in phenology</td>
<td>Deficiency symptom</td>
<td>Cause of deficiency</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------</td>
<td>-------------------------------</td>
<td>----------------------------</td>
<td>-------------------</td>
<td>---------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Important element in young actively growing leaves and during flowering. Important in the plants' energy system. Important to produce plant growth regulator group auxins. Synthesis of nucleic acids. Normal function of certain enzyme systems.</td>
<td><strong>Leaf:</strong> 40 - 100 ppm.  <strong>Soil:</strong> 5 - 20 ppm.  <strong>Fruit:</strong> &gt; 30 ppm (Nov) and &gt; 50 ppm (Feb).</td>
<td><strong>Foliar application:</strong> Due to better bioavailability of chelated fertilizers, the application of a chelated Zn can be advised. Otherwise, 2-3 Foliar sprays of Zinc Oxide (75 %) at a rate of 200 g/100 L or 0.6 - 1 L / ha or Zn (20 %) + Mn (12.5 %) suspension at a rate of 2 - 4 L/ha (200 - 400 L water/ha) during spring and autumn flushes.  <strong>Soil application:</strong> Zinc sulphate (35 %) at 5-10 g/m² ground area covered by tree canopy. Always place Zn in 2-4 small heaps and NOT broadcasted under the tree.</td>
<td>Apply on young growth during spring flush. Mobile in xylem and found in plant sap as an ion. Zn is radically transported across the root to the endodermis through the symplast to the xylem.</td>
<td>Yellow strip along side-ribs (tram tracking) while midrib and base remain green. New leaves are small and curled. Short internodes leading to ‘rosetting’.</td>
<td>Alkaline soils (high pH). High levels of organic matter. High levels of Phosphorous in the soil. Cool, wet weather conditions.</td>
<td>Abercrombie 2011; Sheard 2009; Crous &amp; Retief 2010; Agrichem</td>
<td></td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>Important for protein formation and protein development in the plant. Form biotin and thiamin vitamins. Help plant to withstand low temperatures. Carbon dioxide assimilation. Synthesis of oils. Adequate S levels aids uptake of N.</td>
<td><strong>Leaf:</strong> 0.2 - 0.6 %.  <strong>Soil:</strong> &gt; 20 ppm.</td>
<td>Sulphur can be applied in the forms of gypsum (CaSO₄) in the soil at a rate of 1-3 tons/ha or together with K in the form of KSO₄ at 10 g/m² of ground area covered by tree canopy.  Liquid sulphur (25 % S, 11 % N) can be applied as a foliar spray at a rate of 5 - 7 L/ha.</td>
<td>Apply when applying lime in the soil. Transported via xylem to new shoots and then becomes immobilized. Little downward movement occurs in phloem. If limited, S becomes redistributed from roots and petioles to younger tissue. No translocation</td>
<td>Acidic soils (low pH). Sandy, light poorly structured soil. Low levels of organic matter. Waterlogged soils. Dense, poorly aerated soils.</td>
<td>Abercrombie 2011</td>
<td></td>
</tr>
<tr>
<td>Function / Required for:</td>
<td>Norm</td>
<td>Nutrient application examples</td>
<td>Essential time in phenology</td>
<td>Deficiency symptom</td>
<td>Cause of deficiency</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
<td>------------------------------</td>
<td>-----------------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Copper (Cu^{2+})</td>
<td>Plant function and enzyme activation. Catalyst in photosynthesis and respiration.</td>
<td><strong>Leaf:</strong> 5 - 15 ppm. <strong>Soil:</strong> 3 - 10 ppm.</td>
<td>Apply in small quantities as foliar spray.</td>
<td>Deficiency from old to young leaves.</td>
<td>Fungicide treatments containing Cu can supply sufficient amounts.</td>
<td>Agrichem</td>
<td></td>
</tr>
<tr>
<td>Sodium (Na^+)</td>
<td>Synthesis of chlorophyll. Important role in photosynthesis.</td>
<td><strong>Leaf:</strong> &lt; 15 ppm. <strong>Soil:</strong> &lt; 20 ppm.</td>
<td>Apply in small quantities as foliar spray.</td>
<td>Deficiency symmetry</td>
<td>It is rarely required to alleviate deficiencies.</td>
<td>Agrichem</td>
<td></td>
</tr>
<tr>
<td>Chloride (Cl^-)</td>
<td>Required in small quantities.</td>
<td><strong>Leaf:</strong> &lt; 25 ppm.</td>
<td>Not generally applied to alleviate deficiencies.</td>
<td>Deficiency</td>
<td>Avocado severely susceptible to excess Cl.</td>
<td>Agrichem</td>
<td></td>
</tr>
<tr>
<td>Iron (Fe^{2+}, Fe^{3+} or Fe^{3+})</td>
<td>Required in small quantities. Important for chlorophyll formation and hence the absorption of sunlight energy for photosynthesis. Synthesis of proteins.</td>
<td><strong>Leaf:</strong> 50 - 150 ppm. <strong>Soil:</strong> 4 - 20 ppm. <strong>Fruit:</strong> &gt; 40 ppm (Nov) and &gt; 60 ppm (Feb).</td>
<td>Iron chelate (9 % Fe) can be supplied through the irrigation in calcareous soils, or as a foliar spray at a rate of 4 - 8 L/ha. Liquid Fe with a nitrogen carrier (13 % Fe, 14 % N, 6.5 % S) can be applied as a foliar spray or through the irrigation at a rate of 0.5 - 1 L/ha. Mobile in xylem and mostly moves to chloroplasts. No translocation from old to young leaves. Fe levels are controlled by the reversible binding with ferric phosphoprotein and phytoferritin. Chlorosis (yellowing or in worst cases bleached white) of areas between leaf veins while veins and midrib remain green. Brown necrotic areas develop on leaf. Stunted or thinned</td>
<td>Deficiency</td>
<td>Excessive Zn depress Fe uptake. Calcareous or limestone type soils with a high soil pH. Applications of calcium carbonate (lime) can cause lime induced chlorosis. High levels of B, Cu or Mn. High P levels reduce the solubility of Fe. N accentuates Fe deficiency</td>
<td>Agrichem</td>
<td></td>
</tr>
<tr>
<td>Function / Required for:</td>
<td>Norm</td>
<td>Nutrient application examples</td>
<td>Essential time in phenology</td>
<td>Deficiency symptom</td>
<td>Cause of deficiency</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>------</td>
<td>------------------------------</td>
<td>----------------------------</td>
<td>-------------------</td>
<td>---------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Manganese (Mn⁺)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Agrichem</td>
<td></td>
</tr>
<tr>
<td>Required in small quantities. Cofactor of enzymes responsible for catalyses of nitrate to nitrite. Important for photosynthesis where carbohydrates are formed as a source of energy. Synthesis of Proteins. Pollen germination and growth of the pollen tube.</td>
<td>Leaf: 50 - 250 ppm. Soil: 6 - 40 ppm.</td>
<td><strong>Soil application:</strong> MnO can be applied through the soil when deficiency symptoms occur. <strong>Foliar application:</strong> 4 - 8 L/ha with 6 % Mn chelated product or 2 -4 L/ha (water: 200 - 400 L /ha) Zn (20 %, 0.2 micron) and Mn (12.5 %) suspension during first active growth flush in October, and repeated during summer flush is needed.</td>
<td>Too much Mn is more of a problem than too little. Increase the soil pH to decrease Mn uptake. Like Ca and Mg, the uptake of this cation is competitive. Relatively immobile in plants. Translocated via xylem as Mn²⁺ or weakly combined with organic acids. Concentrates in growth points (meristematic tissue).</td>
<td>Young mature leaf develops dull, yellow mottled appearance, first near midrib and then extended to outer leaf edge. Leaf size and shape remain normal.</td>
<td>Light, sandy poor structured soil. Organic soil. Alkaline soil (high pH). Periods of cool, wet weather. Mg²⁺ and Fe²⁺ depress Mn⁺ uptake due to competition. Liming can limit Mn⁺ availability. Nitrate (NO₃⁻) fed plants take up more Mn than ammonium (NH₄⁺) fed plants.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function / Required for:</td>
<td>Norm</td>
<td>Nutrient application examples</td>
<td>Essential time in phenology</td>
<td>Deficiency symptom</td>
<td>Cause of deficiency</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>------</td>
<td>------------------------------</td>
<td>----------------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic matter</td>
<td>Provide aerobic conditions and a source of carbon to the soil system.</td>
<td>1% = ± 30 kg N / ha / yr.</td>
<td>Supplied through mulch and by filling trenches with compost.</td>
<td>Apply before root flushes twice a year.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Avocado deficiency symptoms

Boron (B) deficiency symptoms: Yellowing of leaf edges on young avocado growth (left) and typical shot-hole symptoms in spring flush leaves (right).

Photo: Agrichem (left) and E. Joubert (right)

Distorted avocado fruit to stem connection.

Photo: Agrichem
Manganese (Mn) deficiency symptoms: Interverinal chlorosis of young, fully extended avocado leaf.

Photo: Agrichem
Zinc (Zn) deficiency symptoms: Little-leaf and “rosetting” of new avocado growth.

Photo: Agrichem
Iron (Fe) deficiency symptoms: Green veins and interveinal chlorosis of young avocado leaf.

Photo: Agrichem
Sulphur (S) deficiency symptoms: Yellowing of young avocado leaf in comparison to healthy leaf on the right.

Photo: Agrichem
Magnesium (Mg) deficiency symptoms: Interverinal chlorosis spreading towards the base and midrib of the avocado leaf.

Photo: Agrichem (left) and E. Joubert (right)
Potassium (K) deficiency symptoms: Interverinal chlorosis and later the formation of light brown spots scattered across the narrow leaf.

Photo: Agrichem
Phosphorous (P) deficiency symptoms: Bronze colour and small leaf size of young avocado leaves.

Photo: Agrichem
Nitrogen (N) deficiency symptoms: Uniform yellowing of leaves, some with curled-up margins.