/ Dr. Oded Achilea, November 30, 2022

A. Some botanical facts

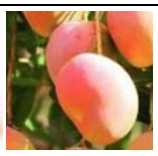
Mango (*Mangifera indica*) crop is a vigorous evergreen tree, belonging to the *Anacardiaceae* botanical family, that also hosts other important crops i.e., cashew, pistachio, sumac and marula. It is native to tropical and subtropical areas in Malaysia, but a few species occur in temperate regions too. Its cultivation spread to neighboring countries, becoming an important horticultural crop in South-East Asia, since nearly 6000 (!) years. Mango is one of the most important fruits of tropical regions, in most of which it is grown only for local consumption, but it is also exported massively. It can start bearing on the 3rd-4th year after planting, and can last, be fruitful and- economically viable, for many tens of years, given that the plantation has been planned carefully, regarding all relevant parameters, and judiciously managed, during its entire commercial life-span.

The mango root system is a combination of fine (≤5 mm in diameter), highly branched surface roots and large (up to several cm in diameter), occasionally branched tap roots. The fine, surface roots play an important role in both nutrient and water uptake, while the larger roots, which can grow many meters deep, mainly anchor the tree in the soil and take up water. The fine roots constitute 77% of the root system, and are found concentrated at depths of 20-40 cm. In commercial irrigated plantations, the root system is concentrated around the wet areas, highlighting the need for fertilization in this area.

B. An extremely wide range of cultivars

Considering the thousands of years of growing, isolating and breeding this crop, hundreds of cultivars have been developed, to comply with a large array of growth conditions, and to satisfy the preferences of consumers belonging to very different people's races, tastes, eating habits and cultures.

The fruits of some commercially important Mango cultivars

'Palmer'	'Kent'	'Suvarnarekha'	'Haden'	'Keitt'	'Nam Doc Mai'	'Tommy Atkins'
						

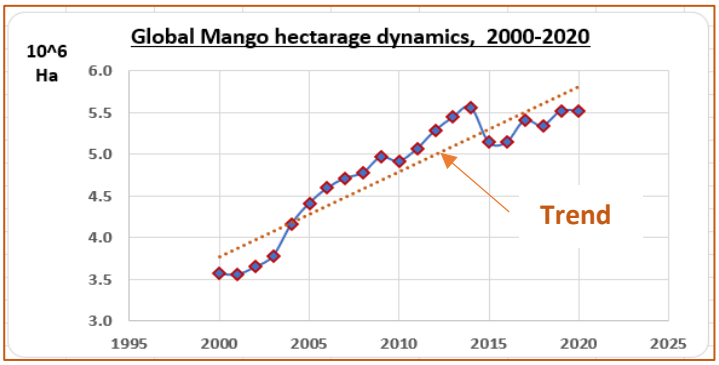
C. A crop of increasing worldwide demand

Following bananas (at 29.4%), Mango, accounting for 28.2%, is the second most consumed fruit in the world. Worldwide cultivation of mango in 2020 is estimated at 5.7 million ha, producing some 54 million MT/Y (metric ton per year), (~9.5 MT/ha metric ton per hectare). (Reference: Statista, 2022).

Seventy five percent of global production is concentrated in Asia, mostly India (45%), Indonesia (6.6%), China (4.3%), Pakistan (4.3%), Thailand (3%) and Bangladesh (2.7%), followed by North-

and South- America (mainly Mexico and Brazil), with about 10% share. African Malawi and Egypt are the chief African protagonists.

The harvested area of mangoes follows almost a monotonous increase trend in 2000-2020. (Reference: FAOSTAT, 2022).



D. Optimal growth conditions

Soils

Mangoes can thrive planted on a wide range of soil types, but it grows best on deep (>2 meters), loamy, or sandy-clayey soils, rich in organic matter, well drained, but featuring also good water-holding capacity, not necessarily fertile. Topography: flat to moderately sloping, within 600-800 meters above sea level, whereby ~400 m is considered ideal.

Optimal soil pH: 5.8–6.5. Higher soil pH is specifically problematic in arid zones, and pH>7.5 strongly limits the uptake of micro-nutrients by most plants' roots, including mangoes. So, such values provoke acute deficiencies of trace-elements, which, in turn, reduce vegetative development and productivity. Certain deficiency cases (e.g., boron and calcium) also strongly affect fruit quality, and post-harvest storability.

This crop is intolerant to saline conditions, such conditions will reduce its yield quantity and fruit quality. However, some varieties that are tolerant to medium (15%) lime content, and to highly saline (>600 ppm) irrigation water, serve successfully as standard rootstocks at such conditions (e.g., Israel).

Temperature, altitudes, rainfall and flower induction

The mango is naturally adapted to tropical lands between 25°N and 25°S off the Equator, and up to elevations of ~900 meters. The crop requires plenty of sunshine for optimum growth and fruiting. Ideal temperature range is 21–27°C. At slightly cooler regions it may suffer cold damages. It does well in annual rainfall range of 750-2500 mm, in the four summer months (June to September) followed by 8 months of dry season. It requires several (3-5) months of dry season, which are necessary for natural flowering induction.

Water management for young trees

Under surface irrigation (e.g., basin and furrow), weekly intervals are essential. With micro-irrigation the requirement is lowered to only ~33% of the water required for conventional methods. Therefore, drip irrigation, micro-jets and micro-sprinklers save water, and are

commonly used on most young and mature plantings. But reduced irrigation rates, necessarily require more frequent irrigation sessions, e.g., daily, or once every two days.

Fertigation (application of fully soluble fertilizers via the irrigation system) in mango is instrumental in getting higher nutrient- and water- use efficiency. On top of saving water, these advanced cultivation methods, enhance plants development rate, and boost their entering into fruit- bearing stage. Moreover, the irrigation management is a potent tool, helping the grower to determine the depth of the active root system, and to better control the performance of the plantation. There is high variability regarding the local growing conditions of mango plantations, in terms of soil texture and depth, temperatures, precipitation timing and rates, evapotranspiration rates, rootstock characteristics, etc. Therefore, we can provide an exact irrigation regime only if we know the exact parameters mentioned above.

We do recommend, however, the interested grower to contact **Gat Fertilizers**' agents to enjoy our knowledgeable agronomic consultancy, for planning the best irrigation, and mineral nutrition regimes.

Being a manufacturer of advanced quality specialty fertilizers, **Gat Fertilizers** focuses on advanced mango growers. Therefore, the entire current publication will focus on growing mango plantations by the most advantageous methods.

Water management for bearing trees

Adult mango trees' grown by conservative methods have effective root system that may reach 1.2 m deep, with lateral spread up to 7 m. Accordingly, trees height may reach 10 meters, which is very costly and inefficient to manage and to harvest. They are usually irrigated by conventional methods such as flood, basin, ring and furrow. But modern irrigation strategies of dripping and mini sprinklers are now at global rise, and offer much more intensive and efficient management methods. We recommend adopting the following methods for optimal crop performances.

Water management for bearing trees

Modern irrigation strategies employ dripping and mini-sprinklers systems.

Adult trees should be irrigated at relatively very low rates, or even totally avoid irrigation, some 2-3 weeks prior to normal flowering time, in order to promote flower-induction. This treatment increases annual production by ~10%, and reduces water consumption by 20%. This drought stress does not reduce fruit size.

- Medium rates and short intervals should be applied at flowering and fruit-set to reduce flower-, and fruitlet abortion, and at final fruit ripening.
- But as plant water requirement increases dramatically during fruit development, recommended drip irrigation intervals are 2-3 days in heavy soil and 1 day for light soil, from fruit-set to fruit maturity, for improving fruit bulking up and its

E. Fertilization guidelines

Young plantations

Preplant management

We strongly recommend to improve soil quality before planting by bringing soil pH to the range of 5.8-7.0, and to bring soil organic matter contents to 1-3%.

Young trees must be fertilized very carefully, since their roots could be easily scorched by excessive fertilizer concentration. Fertigation and micro-irrigation are optimal methods for applying the fertilizers at an effective and economical way. They should be carried out by many applications, throughout the year. See our general plan in the following table, it applies for all soil and climate types.

Tree age (years)	Fertilizer type & N-P_2O_5-K_2O analysis	Number of annual applications	Application rate (kg/ha/irrigation event)	Total annual rate N-P_2O_5-K_2O (kg/ha)	Total annual fertilizer rate (kg/ha)
1	Gatit+TE 14-28-18	25	12	42-84-54	300
2	Gatit+TE 18-18-18	25	16	72-72-72	400
3	Gatit+TE 20-10-20	25	20	100-50-100	500

Please note, the above application rates refer to fertigation carried out by micro-irrigation, whereby only the drippers / mini-sprinklers that are close to the trees are active. In case the entire plantation area is irrigated and fertigated, the fertilizers application rate should be doubled.

We warmly recommend to test the local soil and irrigation-water (indicating testing methods), and to send us the analysis data. This will help us to customize our fertilization guidelines to correspond to the actual field conditions, for optimizing plants development, and to precede trees' fruit bearing phase.

Fruit bearing plantations, indications for estimation of application timing and rates

Key nutrients

The four key nutrients for mango production are nitrogen (N), potassium (K), calcium (Ca) and boron (B). Understanding the interactions of these 4 nutrients is the key to good productivity and fruit quality in mangoes.

Nitrogen is the driver in plant processes. I: It is the most important element for growth, yield, and fruit quality. II: It is essential for chlorophyll production, which in turns produces the sugars, required for tree growth and development. Nitrogen is readily translocated in the tree and this can be seen when newly emerging flush 'yellows off', when flower panicles appear soon after. Important positive effects of well-timed adequate quantities of N include: increasing tree vigour, in conjunction with K, stimulating flowering, and improving fruit set, retention, yield, size and fruit sweetness.

Poorly timed or excessive amounts of N, however, can have significant negative impacts by promoting excessive or unwanted flush, which can prevent Ca from entering the fruits, and can reduce fruit coloring when ripe, and fruit firmness, and increased post-harvest diseases and disorders. Excessive N can also negatively affect yield, by reducing flowering.

Potassium has several key roles in a mango plant. I: It is required for cell division and expansion during all growth phases, but particularly during fruit development. II: It controls plant water uptake, and, therefore, the uptake of other nutrients, by regulating the opening and closing of the stomates. III: It helps sugars movement throughout the plant. Key advantages of appropriate K levels are increased fruit size, and better color of the fruit skin and flesh, and better flesh flavour. Potassium is very mobile in both the soil and plant. It competes with Ca, Na, NH_4 and Mg, for uptake, so ensure that excessive amounts of K are not applied early in fruit development to outcompete the uptake of Ca. Potassium is required during cell division so apply it post-harvest, during flowering and especially during fruit filling.

Some application guidelines. I: It is easily leached, so apply often, at small amounts, particularly in lighter soil types. II: Apply ~70% of the required amount during the fruit filling period. III: Adjust the total amount with the expected crop load, i.e., apply more when a heavier crop is expected. Split potassium fertilizer into multiple small applications during fruit development. It should be best done via a fertigation system, where the fertilizer is dissolved and applied with the irrigation water.

Calcium is a building block of plant cells, where it has two main roles. I. Strengthening cell walls, yet keeping them elastic, allowing the cells to expand as they grow. II. It is essential in all new growing points of mangoes, including roots and root hairs, leaves, flowers and pollen tubes. Calcium is very abundant in all parts of the mango tree. From this point of view, it behaves as the third macro-nutrient. Mango is a unique crop regarding this phenomenon.

Unlike N, calcium, does not move within the plant, so it stays in old tissues. Uptake by young roots is passive, with the transpiration stream, so soil must be moist for Ca uptake to occur. Potassium, Mg, sodium (Na) and ammonium (NH_4) compete with Ca for uptake through the roots. Calcium is difficult to get into the fruit, and uptake speed depends on particle size, smaller Ca particles size ensuring better uptake. As calcium is important for all growth events, it needs to be available all year round. It is especially important for Ca to be readily available to the plant in the first 6-10 weeks of fruit development, or until the seed starts to harden. During this period Ca is drawn into the flesh via water that is lost through the stomates, (the pores in the skin of the fruit and leaves). The end of this time coincides with the turning of the stomates on the fruit skin into lenticels and reduced transpiration. Calcium is important for fruit firmness, shelf life and internal quality. Fruit Ca deficiency symptoms are not visually evident while on the tree, but will show up as internal disorders like soft nose, jelly seed and reduced shelf life.

Boron has several roles. I: It is necessary for all new cell growth, where it affects the movement of plant hormones and sugars. II: It is essential for fruit-set, as it improves pollen viability, and pollen tube growth. III: It is a key component of cell walls and helps calcium move to the cell walls. Boron is highly soluble and is leached very easily from soils, but is barely translocated within the plant. Small amounts are required during all growth phases, but the

majority is required during pollination, and early fruit development. As it is needed in small quantities, high care should be taken to avoid going from deficiency to toxicity.

It is recommended to apply small amounts frequently, particularly on lighter soil types, to avoid losses due to leaching. Foliar applications can only be absorbed by soft tissue, like new flush or flower panicles. Using a small amount of N will help with absorption or uptake.

Advice on application timing and rates for fruit-bearing mango trees

Once trees are bearing, the timing of fertilizer applications is as important as the quantity applied. Excessive fertilization at the wrong time can negatively affect fruit quality. When the trees start bearing fruits, it is the removal of these fruits by harvesting that causes the main nutrient losses from the plantation soil, due to their uptake into the fruits. But additional fertilizers should be applied to support the vegetative development waves that consume nutrients, and would, otherwise, thin and deplete the current nutrients contents of the tree. Many studies were devoted to finding the relevant data, as a prerequisite for rational fertilization programs, considering the local soil, weather, water, cultivar and management conditions. The following table shows characteristic nutrients removal ranges.

Removal values of macro-, secondary- and micro- nutrients, by 1 MT of mango fruits (mature trees of *'Tommy Atkins'* cultivar in Mexico). Ref.: Mellado-Vázquez, 2019; Guide for Australian mango growers, 2017.

Nutrient	Kg		Nutrient	g
N	0.9-1.5		B	4.3
P	0.12-0.25		Cu	1.2
K	1.2-2		Fe	6.0
S	0.08		Mn	5.6
Ca	1.2		Zn	1.5-2.5
Mg	0.09			

This table presents figures prevailing in an important mango growth region in Mexico and in Australia. The highest macro-nutrients removed by the fruit are potassium, calcium and nitrogen. Ca actually behaves as the third macro-nutrient, while P behaves as a secondary nutrient. Iron is the micro-nutrient removed at highest rates by the fruits. Mn is second, and B counts third. Zn and Cu are removed at similar rates that feature roughly 22% of the iron. On average, macro-and secondary nutrients occur in mango fruits in the following decreasing mass order: K>N>Ca>P>Mg>S, and micro-nutrients: Fe>Mn>B>Zn>Cu

This table, shows that all nutrients display usually normal variability, within each and every one. The highest macro-nutrients removed by the fruit are potassium and nitrogen (as N 1.4 Kg, K 1.7 Kg per ton of fresh fruit. They are removed at similar rates, between each other, but their order is somewhat different, for specific cultivars, soil types and locations. Ca actually behaves as the third macro-nutrient, while P behaves as a secondary nutrient, and it shows higher variability than N and K. S and Mg are removed at rates that are very similar to each other, and show high variability too. Iron is the micro-nutrient removed at highest rates by the fruits. Mn is second, and B counts third. Zn and Cu are removed at similar rates that feature roughly 28%

of the iron. On average, macro-nutrients occur in mango fruits in the following decreasing mass order: K>N>P>Ca>Mg>S, and micro-nutrients: Fe>Mn>B>Zn>Cu

The above rates dictate the actual mineral nutrition management. But they may be different in the depending of the cultivar and growth conditions. **This fact increases the importance of getting from you, our dear customer, the actual contents of the nutrients of the fruits of YOUR cultivars.**

Annual leaf analysis is of prime importance for creating an effective fertilization plan

In fruit-bearing orchards, soil analysis is recommended at least once every two years, in order to get an indication about its fertility status. However, it may not provide a satisfactory index of nutrient availability, and to produce misleading information, as it might indicate sufficiency of a nutrient, while the roots may not be able to take up the entire amount of the said nutrient. Additionally, soil pH, salinity or antagonism between elements may hinder nutrient uptake.

Therefore, an annual leaf analysis is an excellent complementary tool, providing very accurate information about the actual contents of the various nutrients in the tree.

Leaf collection procedure

Usually, best timing is 1-2 weeks before harvest, and definitely, before any treatment of foliar application of nitrates, or other foliar fertilizer, done for breaking the dormancy of the floral buds. Twenty healthy trees can represent up to a 10-hectare block. The leaves should be taken from the median part of mature shoot of the penultimate vegetative flush (4-7 months old). Four, entire (blade + petiole), healthy leaves should be collected per tree, one from each side of the plant, (north, south, east and west), at the median height of the canopy.

Optimal nutrients' concentrations of mango leaves, collected according to the said procedure*.

N	P	K	Ca#	Mg	S
(% in dry matter)					
0.84-1.53	0.09-0.15	0.77-1.33	1.4-2.8	0.40-0.65	0.08-0.18
# Mango is a unique crop with such high leaf Ca concentration					

B	Cu	Fe	Mn	Zn
(ppm in dry matter)				
40-100	10-30	70-200	57-174	25-40

*The above values are the means of values cited in many professional articles and text books.

The principal considerations practiced in determining fertilizer application rates

When **micro-irrigation** and fertigation are practiced, at least four important factors must be taken into consideration. They are:

A. Expected fruit load. Fertilizers application rates should correspond to the actual removal rates, found by laboratory analyses of the latest fruits, harvested from the plantations.
B. Soil analysis, that indicates the current availability of the nutrients in the soil. We warmly recommend testing the local soil and irrigation-water, while mentioning the testing methods, and to send us the analysis data. This will help us to customize our fertilization guidelines to the actual field conditions, for optimizing plants productivity and vegetative development.
C. Leaf analysis, that reports the actual contents of these nutrients in the trees. This issue is elaborated in the following page.
D. N application rates should be increased by some 10-15%, above the figures obtained from the above considerations, to supply the nitrogen for the upcoming vegetative growth wave. However, in regions with high precipitation rates (>700 mm/year), N rates should be increased to ~20%, in order to compensate for nitrogen, lost from the soil by leaching and run-off, provoked by heavy rain showers.

We warmly recommend for both above-mentioned climatic situations, continuous co-application of the fertilizers with the irrigation, throughout the irrigation season, to continuously supply the trees' demand throughout the year, according to their phenological growth stages. Moreover, this fertigation treatment should take place also during the rainy season, at which time minimal water rate should be applied, as technical irrigation sessions, that are intended primarily for delivering the nutrients.

The general framework of the distribution of the nutrients throughout the year, is as follows:

Nitrogen. Some 50% of the N should be applied during fruit growth, as of fruit setting, but its application should be minimized for colored fruit cultivars, to about 10%, during the final 1-1.5 months before harvest time, in order to allow for full color development. The balance 50%, should be applied post-harvest.

Phosphorus. Some 40% of the P should be applied before flowering, and 60%- post-harvest.

Potassium. Some 75% of the annual K rate should be applied between fruit-set and harvest time, and 25% should be applied post-harvest.

Calcium and Boron. They should be applied at three stages. Firstly, shortly before spring vegetative flush; secondly, during flowering; and thirdly, during early- to mid- fruit development period.

Micronutrients. They should be delivered by multiple applications, throughout the year.

Actual fertilization recommendations for fruit-bearing mango plantations

Recommended application rates of N, P_2O_5 and K_2O, for irrigated bearing mango trees, depending on expected fruit load, N in leaf analysis, and P and K in soil tests.

Fertigation via micro-irrigation are optimal methods for applying the fertilizers at an effective and economical way. See our general plan in the following table, it applies for all soil, and climate types, at an expected yield of 30-40 MT/ha. This plan should be adapted according to the local conditions, i.e., expected yield, soil- and water- tests, and leaf analysis. Please send us your actual data and we will provide you with the best fertilizers recipe that will optimize your crop.

Trees phenological stage	Fertilizer type & N-P_2O_5-K_2O analysis	Number of weeks/stage to apply fertilizers	Application rate (kg/ha/week)	Total annual fertilizer rate (kg/ha)	Total annual rate N-P_2O_5-K_2O (kg/ha)
Vegetative, before flowering	***Gatit+TE*** 20-10-20	8	50	400	204 – 90 - 150
Fruit growth as of fruit-set	***Gatit+TE*** 20-10-20	7	28	200	
Post-harvest	***Gatit+TE*** 28-10-10	4	75	300	

The recommendations in the above table are suitable for non-acidic soils, while Gatit S is the best practice for acidic soils.

In acidic soils, Ca + Mg should be added separately, and the N:P:K ratio of the Gatit should be modified.

Fertilization should be stopped 2 weeks before harvest to prevent "soft nose" disorder.

Adjusting soil pH

In many tropical and subtropical mango production regions, soil pH tends to be lower than the critical level (5.5), resulting in reduced availability of important nutrients, mainly P, Ca, Mg and Mo. In such soils the grower must not apply the nitrogen in the form of ammonium, nor urea, as it has a soil acidification effect. Too low soil pH can be controlled by adding substantial amounts of lime (calcium carbonate, $CaCO_3$) or gypsum. In irrigated plantations, in semi -arid regions, it should be applied shortly after harvest, to supply the high demand of Ca by the tree.

Conversely, if soil pH is higher than the optimal value, it should be reduced by application of nitrogen nutrition on ammonium (e.g., ammonium sulphate) and urea fertilizers.

F. Conclusions,

All the above-mentioned nutritional requirements are completely met by various products that belong to the ***Gatit*** family of specialty compound fertilizers, produced by **Gat Fertilizers**, in Israel.

Gatit products are aimed for usage in high precipitation regions (>800 mm/year), facing minimal danger of chloride accumulation in the soil. For most year-round applications it is recommended to use ***Gatit plus micronutrients (20-10-20)***, while our recommended fertilizer for the post-harvest stage is ***Gatit plus micronutrients (28-10-10)***. When continuous application of ***calcium nitrate*** and boron is recommended, the ***Gatit plus micronutrients*** formula should have low nitrogen contents, based on N:P:K ratios such as 1-1-3, 1-2-3, 1-2-4.

The ***Gatit reduced chloride plus micronutrients*** products show great performance at lower precipitation regions (<800 mm/year), solving concrete danger of chloride accumulation in the soil.

Where mango plantation soil is highly calcareous and/or alkaline, the trees can barely take up any iron, and tend to show iron deficiency symptoms (interveinal or complete chlorosis). **Gat Fertilizers**' answer to this problem is the product ***Ferrogat Plus***, made up of a mixture of three different iron chelates, ready to supply available Fe under any soil condition.

Where the plantation is frequently suffering from biotic stresses (e.g., fungal diseases, nematodes, or insect pests) or from abiotic stresses (e.g., heat, chilling, drought, or salinity), it is recommended to integrate in the fertigation solution the product ***Bio Humigat***, containing a highly concentrated solution of humic- and fulvic- acids. This product has a proven experience of strengthening plants resistance to these stresses.

G. Flower Induction

A mango tree needs an external stimulus in order to differentiate its vegetative buds into flower buds. This stimulus can be stresses like heat, chill or drought. Such stresses are rather common in regions having a period without rainfall, or where weather is changing rapidly between seasons. In such regions flower induction takes place naturally. However, regions with a monotonous climate, and similar rainfall throughout the year, are prone to minor flowering rate, leading to low fruit productivity.

H. Nutrient deficiencies, excessive and toxic rates in mango plantations

Nitrogen deficiency causes retarded development, less vegetative growth and reduced fruit production. Excessive N causes disproportionate vegetative growth, reduced floral differentiation, yield loss, reduced fruit coloration and internal quality, and increased susceptibility to diseases.

Phosphorus deficiency may result in weaker root system, restricting the uptake of water and nutrients. These, in turn, slow fruit maturation, induce coarse fruit texture, substantially decrease the yield, slowing vegetative growth, premature leaves drop, drying of branches and enhancing their death.

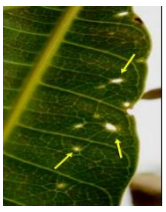
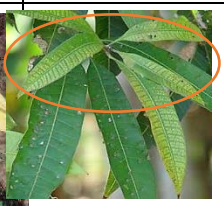
Potassium deficiency symptoms occur in the oldest leaves, as irregularly- distributed small red spots. The leaves are smaller and thinner than normal. At heavier K shortage, the spots coalesce and necrosis of leaf margins takes place. Fruits quality, especially coloration of the skin, aroma, size, and shelf life, are badly reduced. The tree becomes more susceptible to stresses, such as drought, chill, salinity, and to attacks of diseases and pests.

Severe **Calcium** deficiency results in "Soft nose" i.e., fruit pulp collapse, especially, at its blossom-end, and buds' death. Ca deficiency prevails if high Ca rates are not readily available in the soil at greatest Ca requirement, that occurs during the post-harvest vegetative flush, and at the initial development stage of the fruits.

Magnesium deficiency reduces tree development, provokes premature leaves shedding and decreases yield.

Sulphur deficiency is revealed as necrotic spots, and a light green colour of the youngest leaves, that resembles nitrogen deficiency. It provokes slowed vegetative growth and leaf loss. It takes place due to avoidance of application of S- carrying fertilizers.

Main symptoms of nutrient deficiencies in mango trees

N	P	K	Ca	Mg	S
					
B	**B**	**Cu**	**Fe**	**Mn**	**Zn**
					

Boron deficiency symptoms show firstly on the plant's shoot tips. Apical buds death, results in lateral buds proliferation, producing a cluster of secondary branches. The leaves show "Shot holes". The floral panicles are small and have fewer hermaphroditic flowers, consequently

producing fewer fruits. Cv. 'Van Dyke' shows better resistance to B deficiency than cv. 'Haden'. Boron toxicity is presented as necrotic margins on the oldest leaves.

Copper deficiency symptoms are generally shown on young plants, heavily fertilized with nitrogen, and on young shoots of adult plants. It provokes long, tender and S-shaped branches, and downward- curled laminae and central vein of the leaves. Cu deficiency also causes bowl-like eruptions on the branches' bark, sometimes exuding sap. Progressive terminal branch death may occur on curved or
S-shaped shoots.

Iron deficiency is manifested firstly on young leaves, as bright- green or yellowing (chlorosis) of their laminae, contrasting with a mesh of green veins. Severely affected leaves may be pale yellow, with hardly any green veins. In situations of acute deficiency, branches and twigs may dye. Iron deficiency is associated with calcareous- and/or alkaline soils, or with acidic soils, that are very rich in manganese (Mn), or under heavy application of P fertilizer.

Manganese deficiency appears firstly on new leaves, producing yellowish-green laminae, with a noticeable green veins mesh, that are thicker than those associated with Fe deficiency. Severe Mn deficiency provokes necrosis of the laminae margins of new leaves. It causes reduced tree growth, similar to P and Mg deficiencies. It is frequently caused by soil liming and heavy P application.

Zinc deficiency is characterized by interveinal mottled chlorosis of the leaves, they are also small, narrow, curled, thick and rigid. There is less branching and the branches have short internodes, resulting in reduced plant size, and vegetative deformation called "witch's broomstick", floral deformation or "dolling". Zn deficiency can be related to calcareous soils, to heavy liming, and to heavy P fertilizers application.

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