Nutritional recommendations for

CITRUS

Haifa

Pioneering the Future

Nutritional recommendations for

CITRUS

Botanical description: Genus- *Citrus L.*

Contents:

1. Growing citrus

1.1 Growing conditions

Being a tropical and subtropical crop, citrus can be grown in a belt between 40 °N and 40 °S, except at high elevations. Minimum temperature and its duration time are the limiting growth factors sensitivity depends on variety, rootstock, dormancy of the trees and the absolute minimum temperature and its duration.

Intensive citrus cultivation requires the use of fertilizers, close monitoring and control of pests, diseases and weeds, effective irrigation and control of tree size. The trees begin their productive life on the third year, and peak productivity takes place when the trees are 10-30 years old, average yields under these conditions are 30-60 t/ha.

Extensive citrus cultivation requires with the use of fertilizers, but only moderate monitoring and control of pests, diseases and weeds. They are generally rain-fed only. Their productive life starts on the fourth year, and peak productivity takes place when the trees are 8-15 years old, average yields under these conditions are 15-25 t/ha.

1.2 Soil type

Citrus can be grown on a wide variety of soils, from sand to loam and clay. Both acidic and alkaline soils are acceptable.

1.3 Varieties

The genus Citrus is an evergreen tree belonging to the family Rutaceae. It has about 150 genera and 1500 species, all native to the tropical and subtropical regions of Asia and the Malay Archipelago.

The principal citrus scions are:

- Orange (C. sinensis Osbeck)
- Mandarin (C. reticulata Blanco)
- Lemon (C. limon [L.] Burm.)
- Lime (C. aurantifolia [Christ.] Swing.
- Grapefruit (C. paradisi Macf.)
- Pomelo (C. grandis [L.] Osbeck)

The most commonly used rootstocks are:

- Rangpur lime (C. limonia Osbeck)
- Rough lemon (C. jambhiri Lush.)
- Sour orange (C. aurantium L.)
- Cleopatra mandarin (C.reshni Hort.)
- Trifoliata (P. trifoliata [L.] Raf.)

1.4 Climate

Both arid and humid climates are acceptable. As citrus trees are sensitive to low temperatures, the limiting parameter for growing citrus is the minimum temperature prevailing in winter time.

1.5 Irrigation

Irrigation is one of the most important factors in producing a good yield of quality citrus. Irrigation scheduling, knowing how much water to put on and when, has a direct impact on tree health as well as fruit yield, size and quality. Without correct irrigation scheduling, orchard is more susceptible to nutrient deficiencies, physiological disorders, pests and disease.

Correct irrigation scheduling requires an understanding of:

- How much water can be held in the crop root zone
- How much water the crop uses each day
- How much water the irrigation system applies.

Shallow root system

Citrus have a shallow root system. It is important to aim irrigation at the effective root zone, minimizing the amount of water leaching past. For citrus, the effective root zone is usually in the top 30 to 40 cm, depending on the soil type.

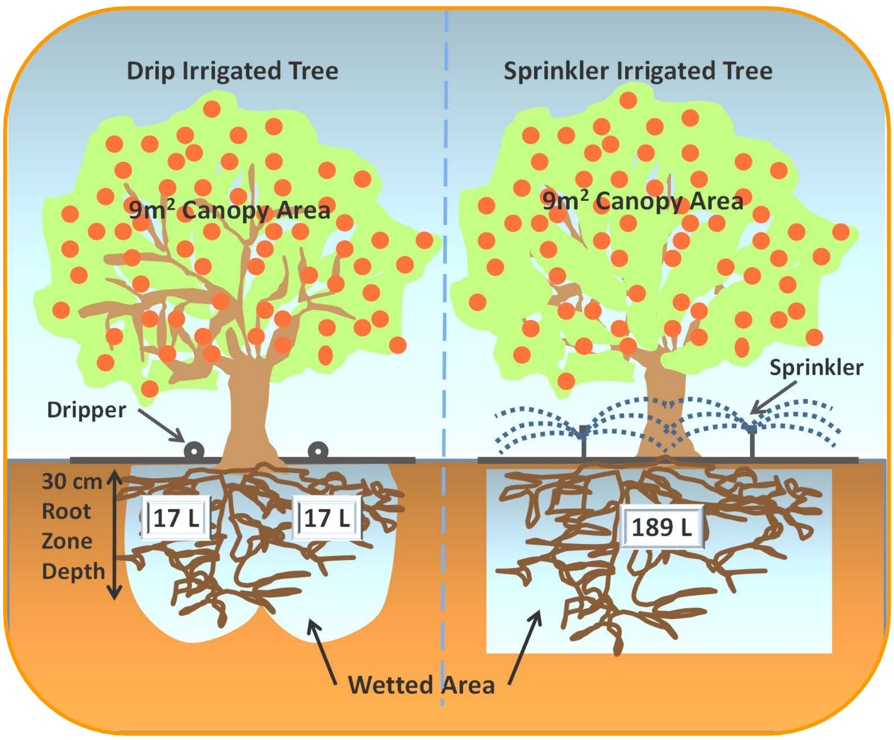
How much water can the root zone hold?

The amount of water that can be held in the root zone and thus available to the tree varies with the irrigation system, soil type, depth of the effective root zone, and proportion of stone or gravel in the soil.

Examples of water holding capacity

Both trees in this example (Fig. 1) are the same size (9 m^2 canopy area) growing in a hedge row in a loam soil. The root-zone depth of both trees is 30 cm. One tree is irrigated with two drippers, the other with a fully overlapping micro sprinkler system. The tree irrigated with two drippers has only 34 liters of readily available water. The tree irrigated with the fully overlapping sprinkler system has a much larger volume of readily available water (189 liters). The more soil is wetted within the root zone, the greater the volume of readily available water.

Figure 1: Example of water holding capacity



Scheduling irrigation

To schedule irrigation, the amount of water available in the crop root zone with the tree's daily water requirement should be compared. If the daily water requirement exceeds the amount of water that can be held in the root zone, there will be a need to irrigate more than once a day. If the soil can hold more than the daily water requirement, there is an option of irrigating when the available water is depleted (this may be every second or third day).

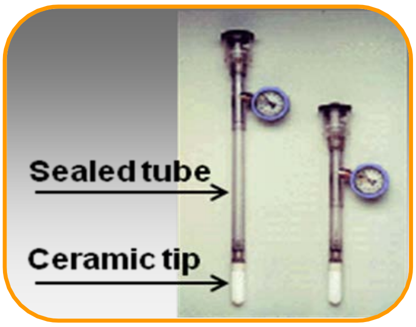
Rainfall during the irrigation season may reduce the irrigation requirement of trees. Not all rainfall is available to the trees; some is lost to run-off, percolation below the root zone, and interception by leaf litter or mulch.

Over-irrigation, especially surface irrigation, may wet the trunks of the trees and increase the incidence of root rot caused by *Phytophthora*. Lime-induced chlorosis can be aggravated by over-irrigation, and tends to be reduced by drip irrigation. Irrigation timing is considered crucial for reproductive development, fruit set and fruit enlargement. However, cropping in one season influences both root extension and top growth, often with a carry-over effect on yield in the successive year.

Recommendations

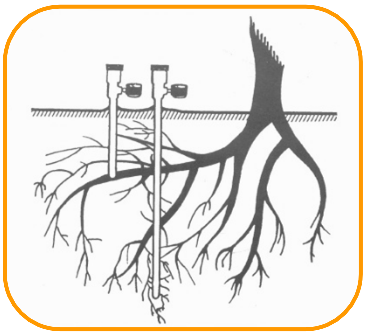
The following recommendations are for healthy and productive orchard. Citrus orchards that above average yield is expected, there is a need to increase the irrigated water quantity by 10% as of the bearing fruit stage (early summer).

Irrigation schedule should start according the soil moisture that can be determined by soil samples with auger or **tensiometers** (a moisture measurement tool). It directly measures the physical force that the root system must overcome in order to access water held in the soil (also known as matric potential).



Placement of tensiometers in the orchard, according to the irrigation method:

- Drip irrigation – 15-20 cm of the second emitter from the tree's trunk.
- Micro-sprinkler – 0.5 m from the mini sprinkler.
- Sprinkler – 1 m from the sprinkler.



Depth placement of tensiometers:

Upper – 20-30 cm deep (most of the active root zone) and the reading from this tensiometer with determine the irrigation schedule.

Lower – 50-60 cm deep, verifies the irrigated depth.

Irrigation intervals will be determent by the age of the citrus orchard or tree size, irrigation method, soil type and the daily water requirement (Table 1).

Table 1: Irrigating intervals (days):

Irrigation method	Drip		Mini sprinkler		Sprinkler
Orchard age / Soil type	Young	Mature	Young	Mature	Mature
Light	1	1	2	1-4	7
Medium	2	3-4	3	2-5	10
Heavy	3	1-5	3	5-7	14

Irrigation of young orchard (up to 4 years from planting):
The water quantities are per single tree and related to irrigation method to the tree size.

Table 2: Drip irrigated young citrus orchard (up to 4 years from planting)

	L/tree/day							Emitters/ tree
	Spring	Late spring	Early summer	Summer	Late summer	Early fall	Fall	
1st year	1	2	3	4	5	5	5	1
2nd year	10	10	10	12	15	15	15	3
3rd year	15	20	22	25	25	25	20	All emitters open
4th year	20	25	30	40	40	40	30	

Irrigation of bearing trees
Due to the variation in water consumption between different growing areas, varieties, expected yield, soil type, drainage problems and so on, it is impossible to provide irrigation schedule that will fit all citrus orchards.

It is important to use additional parameters to determine irrigation schedule:
1. Soil sampling auger
2. Tensiometers
3. Measuring fruit size

How to calculate the water requirement
The daily required amount of water is calculated by multiplying the seasonal **irrigation factor**, varies from area to area and differs according to varieties, by transpiration factor generated from a Class 'A' Pan Evaporation data. To determine the required water quantity, the daily quantity should be multiplied by number of days from the last irrigation (irrigation cycle).

Irrigation factor – is the correlation between the transpiration from the tree and the evaporation from Class 'A' Pan (Evapotranspiration) of a citrus orchard during a particular period.

Group A: Varieties no fear of too large fruit size and plots with above average yield.
Group B: Varieties with low yield and fear of oversized fruits.
Group C: Late grapefruit varieties – yield less than 60 ton/ha, Topaz variety yields less than 40 ton/ha.
Group D: As of late spring, irrigation according to fruit size.

Table 3: Irrigation factors according to different citrus groups

Group	Spring	Late spring	Early summer	Summer	Late summer	Early fall	Fall	Late fall
A	0.30	0.38	0.45	0.52	0.59	0.65	0.71	0.77
B	0.30	0.37	0.43	0.48	0.53	0.57	0.60	0.63
C	0.30	0.35	0.38	0.40	0.40	0.38	0.35	0.30
D	0.45	0.53	0.63	Irrigation according to fruit size				

Example of calculation:
0.55 (irrigation factor) X **7 mm (daily evaporation data from Class 'A' Pan)**
X 4 days irrigation interval = **15.4 mm**, or **X 10 = 154 m^3 water/ha**.

1.6 Planting density and expected yield

Tree spacing is affected by factors such as the species of citrus concerned, the cultivar, type of rootstock, environment, size of the orchard and the management practices the grower will be using. For example, if a grower uses machinery, he must leave enough space between the rows for the machines to pass when the trees are mature. Site quality in terms of soil characteristics and water availability should be considered. Expected lifetime of the orchard is also important and may be influenced by freeze potential, disease incidence, or non-agricultural development potential. Thus, decisions must be based on a number of situations.

Spacing of 6 - 7.5 m between rows and a middle width of 2 to 2.5 m provides adequate access for production and harvesting operations. Within this range, more vigorous trees, such as: grapefruit, lemons, tangelos, and other varieties with more spreading growth habits should be planted at wider spacings than oranges.

Spacing wider than 7.5 m take longer to fill their allocated space, thus reducing early yield potential.

Spacings between rows as close as 4.5 m can be managed with conventional production equipment with timely row middle hedging, however, fruit handling at these closer row spacings becomes a problem.

Spacing in the row of 3 to 4.5 m is considered suitable for new plantings. Tree vigor, site selection and external fruit quality requirements again are important considerations within this range. With the rapid tree growth occurring in many new plantings, trees at this spacing will grow together to form a continuous hedgerow relatively early in the life of the planting.

Spacings less than 3 m in the row have been tried experimentally and in a few commercial plantings. However, trees planted too closely may compete with each other for space at such an early age (before significant production) that the advantage of the higher density does not justify the additional cost of trees. Spacing trees at regular intervals in the row is preferable to grouping trees. For example, regular 3 m spacing is more desirable than grouping two trees 1.5 m apart and then skipping 4.5 m, even though the tree density per an area is the same.

Tree densities range from 286 trees per hectare for the 4.5 X 6.5 m spacing, to 540 trees per hectare for the 3 x 6 m arrangement. Small acreages of densities of up to 865 trees per hectare might be considered on a trial basis.

Tree vigor is of fundamental importance in determining the tree spacing, density, topping, and hedging in new citrus orchards. Citrus tree are flexible and adapt to arrangement of space allocations. Adaptability is limited, however, and maximum economic returns are generated only when tees perform well within their allocated space.

2. Plant nutrition

2.1 Main functions of plant nutrients

Table 4: Summary of main functions of plant nutrients

Nutrient	Functions
Nitrogen (N)	Synthesis of proteins (growth and yield).
Phosphorus (P)	Cellular division and formation of energetic structures.
Potassium (K)	Transport of sugars, stomata control, cofactor of many enzymes, reduces susceptibility to plant diseases.
Calcium (Ca)	A major building block in cell walls, and reduces susceptibility to diseases.
Sulfur (S)	Synthesis of essential amino acids cystin and methionine.
Magnesium (Mg)	Central part of chlorophyll molecule.
Iron (Fe)	Chlorophyll synthesis.
Manganese (Mn)	Necessary in the photosynthesis process.
Boron (B)	Formation of cell wall. Germination and elongation of pollen tube. Participates in the metabolism and transport of sugars.
Zinc (Zn)	Auxins synthesis.
Copper (Cu)	Influences in the metabolism of nitrogen and carbohydrates.
Molybdenum (Mo)	Component of nitrate-reductase and nitrogenase enzymes.

2.2 Nutrient demand/uptake/removal

Removal of mineral elements in the harvested fruit is one of the major considerations in formulating fertilizer recommendations. The table below shows the quantities of nutrient elements contained in one metric ton of fresh fruit. The large amounts of K reflect the high K content of citrus juice.

Table 5: Nutrients removed from the orchard by the fruit

	Grams per Ton of fresh fruit				
	N	P_2O_5	K_2O	MgO	CaO
Orange	1773	506	3194	367	1009
Tangerine	1532	376	2465	184	706
Lemon and Lime	1638	366	2086	209	658
Grapefruit	1058	298	2422	183	573

Table 6: Micronutrients removal from soil, by fruit, of different citrus varieties

Variety	grams per ton of fresh fruit				
	Fe	Mn	Zn	Cu	B
Orange	3.0	0.8	1.4	0.6	2.8
Mandarin	2.6	0.4	0.8	0.6	1.3
Lemon and lime	2.1	0.4	0.7	0.3	0.5
Grapefruit	3.0	0.4	0.7	0.5	1.6

2.2.1 Leaf analysis as a guidance tool for the nutrition of citrus

Using leaf analysis as one of the guides in planning citrus fertilizer programs has yielded a considerable cultivation progress. The table below relates to spring flush leaves, 4-6 months old, from non-fruiting terminals. Leaves from fruiting terminals (used in S. Africa and some S. American countries) have lower N, P and K, and higher Ca and Mg contents than leaves of the same age from non-fruiting terminals, a fact which should be borne in mind when interpreting leaf analysis data.
It is common to sample spring flush of healthy, undamaged leaves that are 4-6 months old on non-fruiting branches (Fig 2a). Selecting leaves that reflect the average size leaf from the spring flush. Typically, 75 to 100 leaves from a uniform 5-hectare block of citrus are sufficient for testing.
In some countries, it is recommended to sample spring grown leaves from bearing shoots, nearest to a fruit (Fig 2b).

Figure 2a: Sample leaves from the middle of non-fruiting shoots as shown above

Figure 2b: Sampling spring grown leaves nearest to fruit

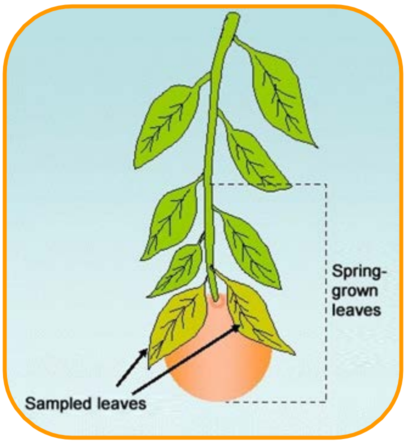


Table 7: Leaf analysis standards for Citrus (Florida)

Nutrient	Type of Citrus	Low(%)	Good(%)	High(%)
N	Naval	< 2.00	2.20 - 2.60	> 2.80
	Valencia	< 1.90	2.10 - 2.40	> 2.70
	Grapefruit	< 1.60	1.80 - 2.40	> 2.60
P	Naval	< 0.09	0.11 - 0.16	> 0.19
	Valencia	< 0.09	0.11 - 0.16	> 0.19
	Grapefruit	< 0.10	0.13 - 0.17	> 0.20
K	Naval	< 0.60	0.70 - 1.70	> 1.80
	Valencia	< 0.70	0.90 - 1.80	> 1.80
	Grapefruit	< 0.50	0.70 - 1.70	> 1.80

2.3 Nutrient deficiency symptoms in citrus

Nutrient deficiency symptoms appear on different plant parts, most frequently on leaves, fruits and roots. The mobility of nutrients is an important property from this point of view. Therefore, nutrients undergoing redistribution process e.g., when plant enters into reproductive- from vegetative phase. Accordingly, various nutrients are classified as very immobile (B and Ca), very mobile (N, P, K, and Mg), immobile (Fe, Cu, Zn, and Mo), and slightly mobile (S). Symptoms are noticed on fruits for immobile nutrients like B and Ca. Development of visible symptoms is accountable to metabolic disorders, which cause changes in micro-morphology of plants before these symptoms are identifiable.

The way in which the symptoms develop and manifest on younger or older leaves, or the fruits, gives a reliable indication about the cause of nutritional disorders. Both deficiency and excess of nutrients can lead to reduction in crop yield, coupled with inferior fruit quality. Mild visible leaf symptoms, for some of the essential element deficiencies, can be tolerated without a reduction in yield in some citrus varieties, but not in others.

Various forms of deficiency symptoms are usually summarized as:

a. Stunted or reduced growth of entire plant with plant remaining either green or lacking in normal green luster or the younger leaves being light colored compared to older ones
b. Older leaves showing purple color, which is more intense on the lower side
c. Chlorosis of leaves either interveinal or the whole leaf itself, with symptoms either on the younger and/or older leaves or both
d. Necrosis on the margins, or interveinal areas of leaf, or the whole leaf on young or older leaves
e. Stunted growth of terminals in the form of rosetting, frenching, or smalling of leaves coupled with reduced terminal growth, or subsequent death of terminal portion of plants

2.3.1 Nitrogen (N)

Function: Nitrogen is one of the primary nutrients absorbed by citrus roots, preferably in form of nitrate (NO_3^-) anion. It is a constituent of amino acids, amides, proteins, nucleic acids, nucleotides and coenzymes, hexosamines, etc. This nutrient is equally essential for good cell division, growth and respiration.

Deficiency Symptoms: Deficiency is expressed by light green to yellow foliage over the entire tree in the absence of any distinctive leaf patterns. With mild deficiency, foliage will be light green progressing to yellow as conditions intensify (Fig. 3a, 3b). New growth usually emerges pale green in color, but darkens as foliage expands and hardens. With yellow vein chlorosis, the midribs and lateral veins turn yellow, while the rest of the leaf remains with normal green color (Fig. 4). This chlorosis is frequently attributed to girdling of individual branches or the tree trunk. It may also occur with the onset of cooler weather in the fall and winter, due to reduced nitrogen uptake by the plant from the soil. Nitrogen deficiency is also associated with senescing foliage, which can develop a yellow-bronze appearance prior to leaf abscission (Fig. 5). Nitrogen deficiency will limit tree growth and fruit production, while high nitrogen applications produce excessive vegetative growth at the expense of fruit production, reducing fruit quality and threatening groundwater, particularly on vulnerable soil types.

Figure 3a: Nitrogen deficiency (Dark green leaf is normal; the other two leaves are deficient.)

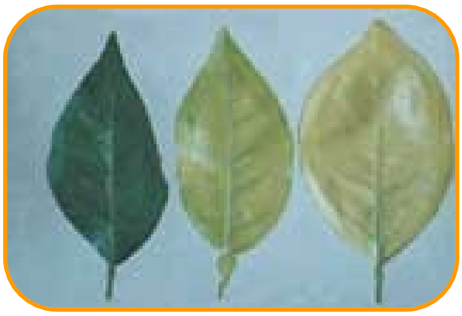
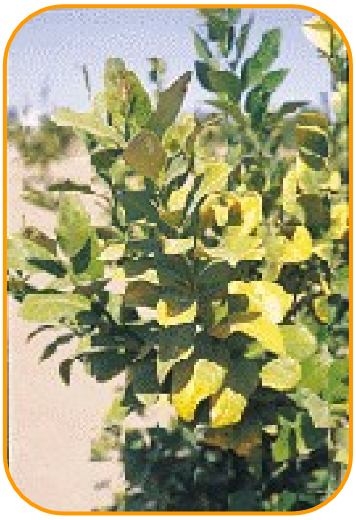


Figure 3b: Nitrogen deficiency (Aging, senescing leaves.)

Figure 4: Pale new growth under N deficiency

Figure 5: Nitrogen deficient lemon foliage. Note that deficiency appears on the older leaves.

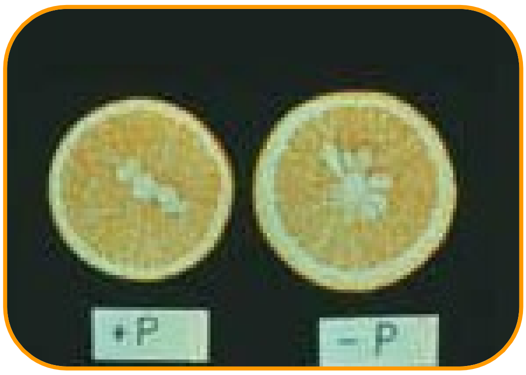


2.3.2 Phosphorus (P)

Function: Phosphorus is one of the three primary nutrients, and is absorbed by citrus roots in the form of orthophosphate (H_2PO^{4-}) or HPO_4^{2-}. It is a component of sugar phosphates, nucleic acids, nucleotides, coenzymes, phospholipids, phytic acid, etc. It plays a key role in the reactions involving ATP. The element is necessary for many life processes such as photosynthesis, synthesis and breakdown of carbohydrates, and the transfer of energy within the plant. It helps plants store and use energy from photosynthesis to form seeds, develop roots, speed-up the maturity, and resist stresses.

Deficiency Symptoms: Phosphorus has the tendency to move from older to younger tissues; therefore, symptoms appear first on older leaves, which lose their deep green color. Leaves turn small and narrow with purplish or bronze lusterless discoloration. Some leaves may later develop necrotic areas, and young leaves show reduced growth rate. Fruits are rather coarse with thick rinds (Fig. 6) and have lower juice content, which is higher in acid. Although rarely observed, foliage may exhibit a bronze appearance. Phosphorus deficiency is unlikely to occur in orchards that have received regular P applications in the past.

Figure 6. Phosphorus deficiency symptoms on fruits



2.3.3 Potassium (K)

Function: Potassium (K) is required as a cofactor for 40 or more enzymes. It is required for many other physiological functions, such as formation of sugars and starch, synthesis of proteins, normal cell division and growth, neutralization of organic acids, regulating carbon dioxide supply by controlling stomatal opening and improving efficiency of sugar use, overcoming environmental stress such as frost by decreasing the osmotic potential of cell sap.

Due to higher ratio of unsaturated/saturated fatty acid, a role in imparting drought tolerance, regulation of internal water balance and turgidity, regulating Na influx and/or efflux at the plasmalema of root cells, chloride exclusion behavior through selectivity of fibrous roots for K over Na, and imparting salt tolerance to cells to enable holding the K in the vacuole against leakage, when Na incurs in external medium.

Table 8: Positive effect of K on yield, fruit size and quality in sweet oranges

K_2O g/tree	Fruit weight g	Yield Kg/tree	Juice %	TSS %	Acidity %
0	165.2	31.9	46.3	9.77	0.549
200	173.1	36.2	47.2	9.89	0.542
400	178.0	37.5	47.2	10.06	0.533

Deficiency Symptoms: Early K-deficiency symptoms are commonly in the form of stunted growth, sparse somewhat bronzed foliage, and a lusterless appearance of leaves. Under acute K-deficiency, the leaves wrinkle and twist, and only weak new lateral shoots emerge, because of lack of mechanical strength. Other symptoms are: reduced fruit size (Fig. 7a, 7b) with very thin peels of smooth texture, premature shedding of fruits (Fig. 11), leaf scorching, appearance of resinous yellow spots, and shoots turning S-shaped.

Figure 7a: K affects the size of orange fruit

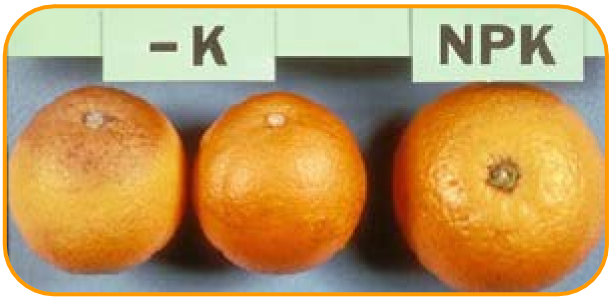


Figure 7b: Potassium deficiency symptoms on fruits (Left one is normal and smallest fruit is the most K-deficient).

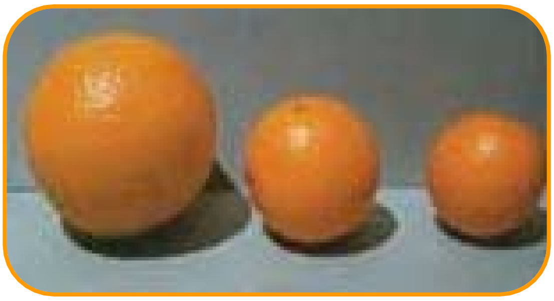


Figure 8: K affecting the rind - have smoother, thinner rinds, susceptible to diseases
Plugging - removal of the peel in the stem-end area of the fruit; increases incidence of postharvest decay

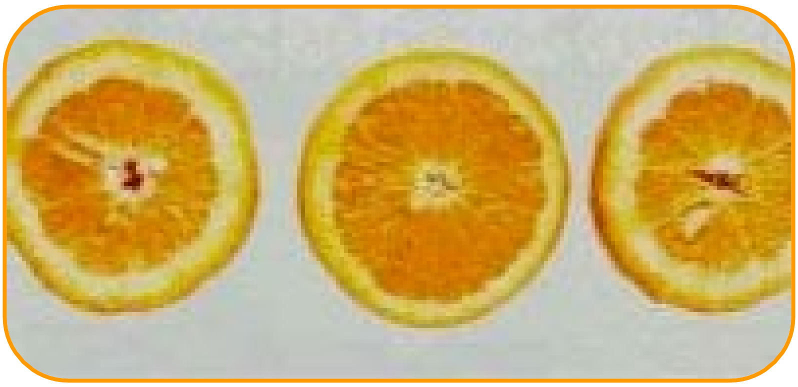


Figure 9: Creasing - rind disorders, albedo breakdown, causing narrow sunken furrows on the rind surface as the peel disintegrates easily.

Figure 10: Splitting – vertical split at the styler or blossom-end and opening longitudinally towards the stem end.

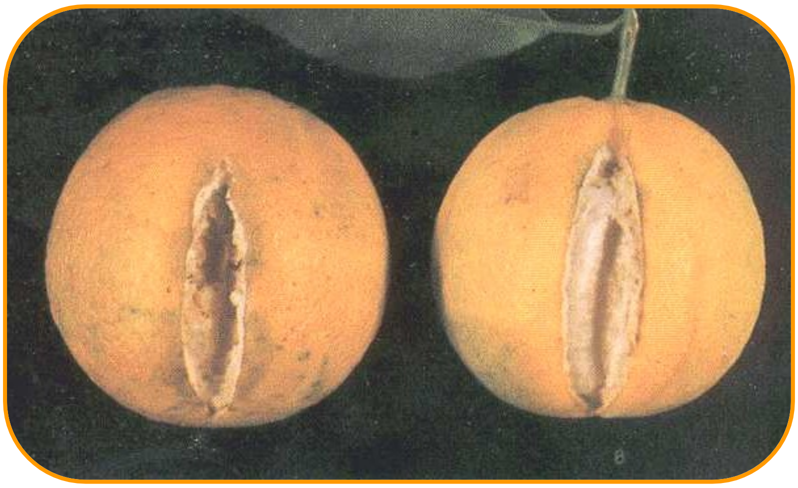


Figure 11: Fruit drop – early fruit drop may occur when K is deficient.

Fading of chlorophyll, appearing as blotches, takes place in distal half of leaf. These blotches appear pale yellow at first, but later deepen to bronze, as they spread and coalesce, with leaf tips turning brown, showing abnormally variegated chlorosis in the form of amarelinho. Appearance of yellow to yellow-bronze chlorotic patterns on older leaves, along with corky veins, is also seen (Figs. 12a-c).
A screw-type of curling towards the lower leaf surface, particularly on lemon is more common. Many a times, fruits attain more growth in the longitudinal direction leaving restricted fruit growth equatorially; eventually fruits turn elliptical in shape.

Figures 12a-c: Chlorosis of older leaves. K-deficient leaves turn golden yellow, and bend downward at the tip and margins

Potassium deficiency is likely to occur on calcareous soils due to elemental antagonism, and where large crops of fruit are produced with high nitrogen rates. A rarely observed bronzing of foliage may sometimes be observed, particularly on lemons. Potassium deficiency is associated with accumulation of cadaverine, acid invertase, lysine, histidine, arginine carboxylase, and reduced activity of carbamyl putrescine amine hydrolase, and pyruvate kinase. These are considered useful biochemical markers for establishing K-deficiency in citrus.

Table 9: Response of citrus yield and quality parameters to K fertilization as indicated by leaf K *

Parameter	**Leaf K** (g/kg dry weight (			
	Deficient	**Low**	**Optimum**	**High**
	7 >	7-11	12-17	18-23
External fruit quality				
Size	→	→	→	→
Weight	→	→	→	→
Rind color	←	←	←	←
Rind thickness	→	→	→	→
Rind Disorders				
Creasing	←	←	←	←
Plugging	←	←	←	←
Splitting	←	←	←	←
Storage decay				
Stem end rot	←	←	←	←
Green mold	←	←	←	←
Internal juice quality				
Juice content	←	←	←	←
Soluble solids	→	→	→	→
Acid	→	→	→	→
Vitamin C	→	→	→	→

Thicker arrow = more pronounced effect

2.3.4 Calcium (Ca)

Function: Calcium is one of the secondary nutrients, absorbed by plant roots as Ca^{2+}. Calcium is a constituent of the middle lamella of cell walls as Ca-pectate. It is required as a cofactor by some enzymes involved in the hydrolysis of ATP and phospholipids. It is an important element for root development and functioning; a constituent of cell walls; and is required for chromosome flexibility and cell division. Calcium deficiency appears to be a special case in which leaf chlorosis indeed reflects a broader interference involving alterations in nitrogen metabolism.

The reduced activity of pyruvate kinase is considered an indicator of Ca-deficiency.

Deficiency Symptoms: Deficiency of Ca is mainly characterized by fading of chlorophyll along the leaf margins and between the main veins, especially during winter months. Small necrotic (dead) spots develop in the faded areas. Small thickened leaves cause loss of vigor and thinning of foliage under severe conditions. Twig die-back and multiple bud growth develop from new leaves with undersized and misshapen fruits having shriveled juice vesicles, commonly referred as bronzing or copper leaf.

Chlorosis along leaf margins, leaves misshapen, often abscise rapidly.

Roots underdeveloped, may decay .Tree shows dieback and stunted Breakdown' Fruits show creasing and cracks form underneath the rind, with splitting and separation of the rind (Fig. 13).

Figure 13: Creasing resulted by calcium (Ca) deficiency

2.3.5 Magnesium (Mg)

Function: Magnesium is another secondary macronutrient absorbed as Mg^{+2}. Magnesium is a central constituent of the chlorophyll molecule. A large number of enzymes involved in phosphate transfer require it nonspecifically. It is involved in photosynthesis, carbohydrate metabolism, synthesis of nucleic acids, related to movement of carbohydrates from leaves to upper parts, and stimulates P uptake and transport, in addition to being an activator of several enzymes.

Deficiency Symptoms: The deficiency of Mg is commonly referred to as bronzing or copper leaf symptoms. Symptoms of Mg-deficiency occur on mature leaves following the removal of Mg to satisfy fruit requirement. Disconnected yellow areas or irregular yellow blotches start near the base along the mid-rib of mature leaves that are close to fruits. These blotches gradually enlarge and coalesce later to form a large area of yellow tissue on each side of the mid-rib. This yellow area gradually gains in size, until only the tip and the base of the leaves are green, showing an inverted V-shaped area pointed on the mid-rib. With acute deficiency, leaves may become entirely yellow-bronze and eventually drop (Fig. 15 a-c). Seedy fruits are more severely affected than cultivars producing seedless fruits. Within the tree itself, heavily fruited limbs develop extreme Mg-deficiency symptoms, and may even become completely defoliated, while limbs with little or no fruits may not show deficiency symptoms. An increase in concentration of alkaline invertase is considered biochemical markers of K-deficiency in citrus.
With acute deficiency, leaves may become entirely yellow-bronze and eventually drop (Fig. 13). Magnesium deficiency occurring in calcareous soil may have to be corrected with foliar applications. Spraying Magnisal®, magnesium nitrate, is an effective treatment to correct Mg^{2+} deficiency.

Figure 14: Severe (left) and moderate (right) Mg deficiency

Figure 15 a-c: Magnesium (Mg) deficiency symptoms on citrus leaves

2.3.6 Iron (Fe)

Function: Iron, a micronutrient, is a constituent of cytochromes, non-haeme iron proteins, involved in photosynthesis, and N_2 fixation and respiratory linked dehydrogenises. Iron is also involved in the reduction in nitrates and sulfates, the reduction in peroxidase and adolase. The increase in carbonic anhydrase activity is considered effective marker of Fe -deficiency.

Deficiency Symptoms: Lime induced Fe-deficiency is the most common form of deficiency. Interveinal white chlorosis due to Fe-deficiency appears first on young leaves. In mild cases, leaf veins are slightly darker green than interveinal areas with symptoms appearing first on new foliage (Fig. 16). In severe cases, interveinal areas become increasingly yellow with entire area eventually becoming ivory in color with emerging foliage, which is smaller. In some cases, leaves remain completely bleached, and margins and tips are scorched. In acute cases, the leaves are reduced in size, turn fragile and very thin, then shed early (Fig 17).
Trees dieback severely from the periphery, especially at the top, and some trees have dead tops with the lower limbs showing almost normal foliage. Trees may become partially defoliated with eventual twig and canopy dieback.
Iron deficiency is usually an indication of calcareous soil condition and is more likely to be expressed on high pH-sensitive rootstocks like Swingle citrumelo. An early expression of flooding damage to roots and of copper toxicity may be iron deficiency symptoms.

Figure 16: Iron (Fe) deficiency symptoms on young citrus leaves

Figure 17: Development of iron (Fe) deficiency in lemon. Left- healthy leaf; right- severe deficiency

Figure 18: Iron (Fe) deficiency symptoms on lemon foliage. Note that leaves are young, but are generally full size.

2.3.7 Manganese (Mn)

Function: Manganese is one of the redox micronutrients, absorbed by the plant roots in the form of Mn^{+2}. It is required for the activity of some dehydrogenases, decarboxylases, kinases, oxidases, peroxidases, and non-specifically by other divalent, cation-activated enzymes, and is required for photosynthetic evolution of O_2, besides involvement in production of amino acid and proteins. Manganese has equally strong role in photosynthesis, chlorophyll formation and nitrate reduction, and is indispensable for the synthesis of ascorbic acid, emerging from secondary effects of the fertilizer. A metalloenzyme peroxidase concentration is considered the marker of Mn deficiency. Accumulation of xylose and increased activity of peroxidase are considered useful biochemical markers of Mn deficiency in citrus in addition to reduced activity of phenylanine lyase, tyrosine ammonia lyase, and polyphenol oxidase.

Deficiency Symptoms: Deficiency appears as dark green bands along the midrib and main veins surrounded by light green interveinal areas (Fig. 19) giving a mottled appearance (Fig. 20). In more severe cases, the color of leaves becomes dull green or yellowish green along the mid-rib, and main lateral veins turn pale and dull for the interveinal areas. Chlorosis appears first on younger leaves, then spread gradually to older leaves (Fig. 21. Stems remain yellowish green, often hard and woody. Young leaves commonly show a fine network of green veins on a lighter green

background, but the pattern is not distinct as in Zn and Fe deficiencies, because the leaves remain green.
Both manganese and zinc deficiencies may occur on calcareous soil and may be more severe on trees with highly pH-sensitive rootstocks. Incipient manganese symptoms may sometimes disappear as the season progresses, so leaves should be observed several times before remedial action is taken. Soil and foliar applications may be effective in correction of manganese deficiency.

Figure 19: Manganese (Mn) deficiency

Figure 20: Mn deficient leaves show mottled appearance

Figure 21: Manganese deficiency symptoms in lemon, showing normal leaf (left) and typical interveinal chlorosis (right).

2.3.8 Zinc (Zn)

Function: Zinc deficiency is a common problem world over. It is an essential constituent of many enzymes such as alcohol dehydrogenase, glutamic dehydrogenase, lactic dehydrogenase, carbonic anhydrase, regulating equilibrium between carbon dioxide; alkaline phosphatase, carboxypeptidase, and other enzymes such as dehydropeptidase and glycylglycine dipeptidase for protein metabolism. It also regulates water relations, improves cell membrane integrity, and stabilizes sulflahydryl groups in membrane proteins involved in ion transport.

Deficiency Symptoms: Little leaf, rossetting, mottle leaf, frenching etc. The young leaves from vegetative shoots are more affected than reproductive shoots. The symptoms of Zn-deficiency are also characterized by irregular green bands along the mid-rib and main vein on a background of light yellow to almost white (Fig 22). Relative amounts of green and yellow tissue vary from a condition of mild Zn-deficiency showing in small yellow splotches between the larger lateral veins, to a condition in which only a basal portion of the mid-rib is green and the remainder of the leaves remain yellow to white. In severe Zn-deficiency, the leaves turn abnormally narrow and pointed with the tendency to stand upright coupled with extremely reduced size (Fig 23). As the deficiency progresses, the leaves are affected over the entire periphery of the tree, and the twigs become very thin and later dieback rapidly. A profuse development of water sprouts takes place. Some of the metallo-enzyme viz., carbonic anhydrase, nitrate reductase, and indole-acetic acid are suggested as biochemical markers of Zn-deficiency.

Figure 22: Zinc (Zn) deficiency

Figure 23: Leaves showing symptoms of severe Zn deficiency

2.3.9 Sulfur (S)

Function: Sulfur is essential for protein formation, as a constituent of the three amino-acids cystine, cysteine and methionine. Sulfur is required for the formation of chlorophyll and for the activity of ATP - sulfurylase. These essential functions permit the production of healthy and productive plants, which are capable of giving high yields as well as superior quality.

Deficiency Symptoms: When plants do not get enough S, they may show visual symptoms of S deficiency. The classical symptom is a yellowing of younger leaves while old leaves remain green. Plants deficient in S often mature late. Symptoms of S deficiency occur particularly in plants well supplied with nitrogen but are sometimes confused with that of nitrogen. In this instance, leaf analysis can be invaluable.
Symptoms: Yellowing of new growth smaller leaves and abscise prematurely. Dieback of new shoots. Fruit undersized and misshapen (Fig. 24)

Figure 24: Sulfur (S) deficiency

2.3.10 Copper (Cu)

Function: Copper plays an active role in enzymes performing key functions like respiration and photosynthesis and Cu-proteins have been implicated in lignification, anaerobic metabolism, cellular defense mechanism, and hormonal metabolism. Known forms of Cu in the plants comprise cytochrome oxidase, diamine oxidase, ascorbate oxidate, phenolase, leccase, plastocyanin, protein having ribulose biphosphate carboxylase activity, ribulose biophosphate oxygenase activity, superoxide dismutase, plantacyanin, and quinol oxidase. Copper proteins exhibit electron transfer and oxidase activity. Ascorbic acid oxidase is widely distributed and responsible for catalysing oxidation of ascorbic acid by oxygen. Copper is also a constituent of cytochrome oxidase and haeme in equal proportions. It also acts as a terminal electron acceptor of the mitochondrial oxidative pathway.

Deficiency Symptoms: copper deficiency is commonly known as exanthema. Wilting of terminal shoots, frequently followed by death of leaves is usually seen in Cu-deficiency.
Mild copper deficiency is usually associated with large, dark green leaves on long soft angular shoots. Young shoots may develop into branches, which appear curved, or “S-shaped,” referred to as “ammoniation” usually resulting from excessive nitrogen fertilization (Fig. 25). Twigs can develop blister-like pockets of clear gum at nodes (Fig. 26). As twigs mature, reddish brown eruptions may occur in the outer portion of the wood. Severely affected twigs commonly die back from the tip with new growth appearing as multiple buds or “witches broom”. Necrotic-corky areas on the fruit surface may sometimes occur in extreme situations (Fig. 27) . Copper deficiency is more likely to occur in new plantings on previously uncropped soils, which are usually deficient or totally lacking in copper.

Figure 25:
Copper (Cu) deficiency in citrus twigs

Figure 26:
Cu deficiency showing gum pocket at node

Figure 27:
Copper (Cu) deficiency - necrotic-corky areas on the fruit surface

2.3.11 Boron (B)

Fruit symptoms most indicative of boron deficiency include darkish-colored spots in the white albedo of fruit and sometimes in the central core (Fig.28). Fruit may be somewhat misshaped with a lumpy surface. Young leaves are dull brown/green, water soaked areas may develop. Leaves are thick, curled with pronounced veins on upper surface. Bark of twigs may split, fruits are small (Figs. 29 a and b).
Unlike other micronutrient deficiencies, boron can affect fruit quality and therefore should be avoided. On the other hand, even slight excess of boron can cause toxicity (see page 30), so maintenance or correctional applications should be done very carefully, involving either soil or foliar applications, but not both.

Figure 28: Boron deficiency symptoms in red grapefruit

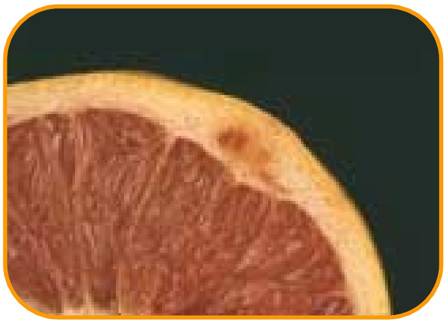


Figure 29 a-b: Boron deficiency symptoms on leaves

2.3.12 Molybdenum (Mo)

Deficiency of molybdenum in citrus is rare. It can occur under acidic soil conditions. The most characteristic field symptoms are large yellow spots on the leaves that appear first as less defined water-soaked areas in spring (Fig.30), later developing into distinct larger interveinal yellow spots.

Figure 30: Molybdenum deficiency symptoms

2.4 Special sensitivities of citrus

2.4.1 Salinity

Citrus is sensitive to high concentrations of salt (sodium chloride) in the soil or in irrigation water. Salt toxicity causes leaf burn and yellowing, starting near the tip. Leaf drop is heavy and dieback follows. Older leaves show the symptoms first.
Citrus is moderately sensitive to salinity: Sensitivity Threshold = 1.7 dS/m;
Yield decline slope (beyond threshold) = 16 % / EC unit (Fig. 31 - 35).

Figure 31: The effect of chloride on citrus fruit yield

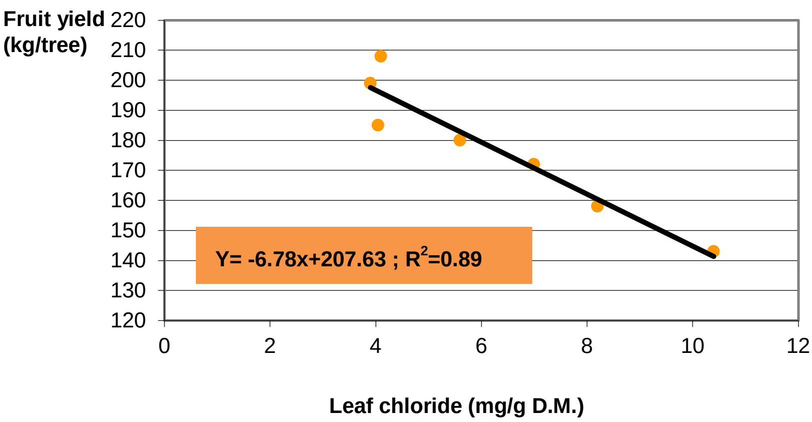


Figure 32: Salinity-resulted tip burn

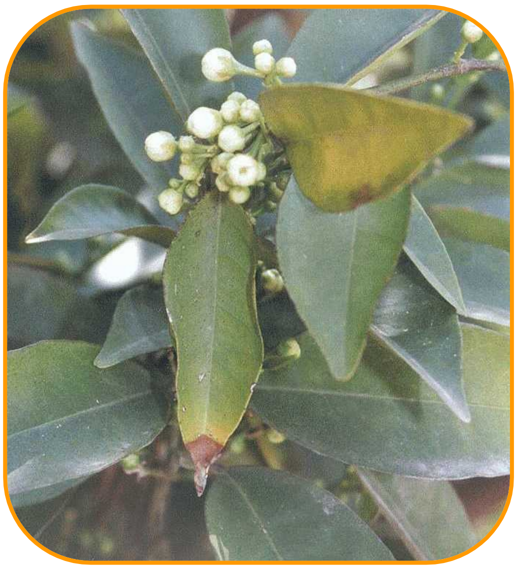


Figure 33: Salinity – Twig dry out

Figure 34: Twig dry out

Figure 35: Wide areas of chlorosis along the margins and between veins of lemon leaves due to high salt concentrations

Symptoms of salt toxicity often begin as yellowing and grey or light-brown burn of the leaf tip. The burn extends back from the tip and then develops along the edges of other parts of the leaf edge. A variable degree of yellowing can develop ahead of the burnt tissue.

The tolerance limit of salinity in the root-zone for 'Valencia' oranges is estimated at an EC of 2.5 - 3.0 ds/m. The growth of citrus species and their fruit yield is generally reduced at soil electrical conductivities (EC) above 1.4 ds/m. Salinity, not only reduces growth and yield due to the osmotic potential effect, but for the same reasoning salinity delays and depresses emergence, reduces shoot and root biomasses.

The use of more tolerant scions and salt-excluding rootstocks helps minimize salt injury to trees and loss of production. Lemons are more susceptible than grapefruits or oranges. Citrus on rough lemon rootstock are more susceptible to salt toxicity than those on Troyer or Carrizo citrange, with sweet orange stock being the most tolerant of the stocks commonly used for oranges.
Poncirus trifoliata rootstock allows high levels of chloride to accumulate in the tree, whereas Rangpur lime and Cleopatra mandarin stocks are the most effective in excluding chloride, where their use is appropriate.

Multi-K® (potassium nitrate - KNO_3) combats successfully salinity by suppressing the uptake of chloride and sodium. The antagonistic effects of nitrate-nitrogen (NO_3^-) and potassium (K^+) suppress these ions, Cl^- and Na^+. The higher concentration of Multi-K® in the soil solution, the better results of combating salinity can be expected (Fig. 36-37).

Figure 36: The Effect of Multi-K® potassium nitrate on chloride content of a citrus leaf under saline conditions. Multi-K® treatment: constant concentration of 200ppm in the irrigation water.

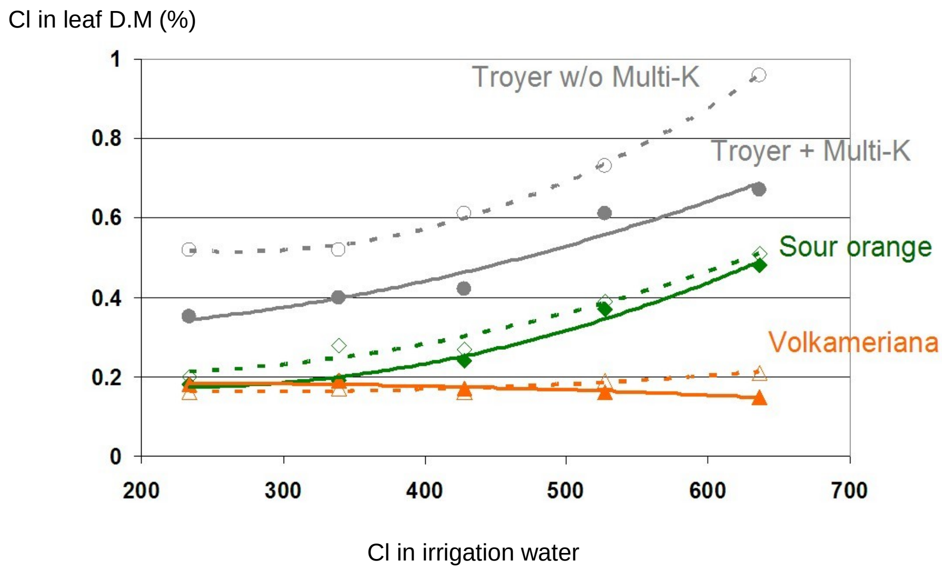
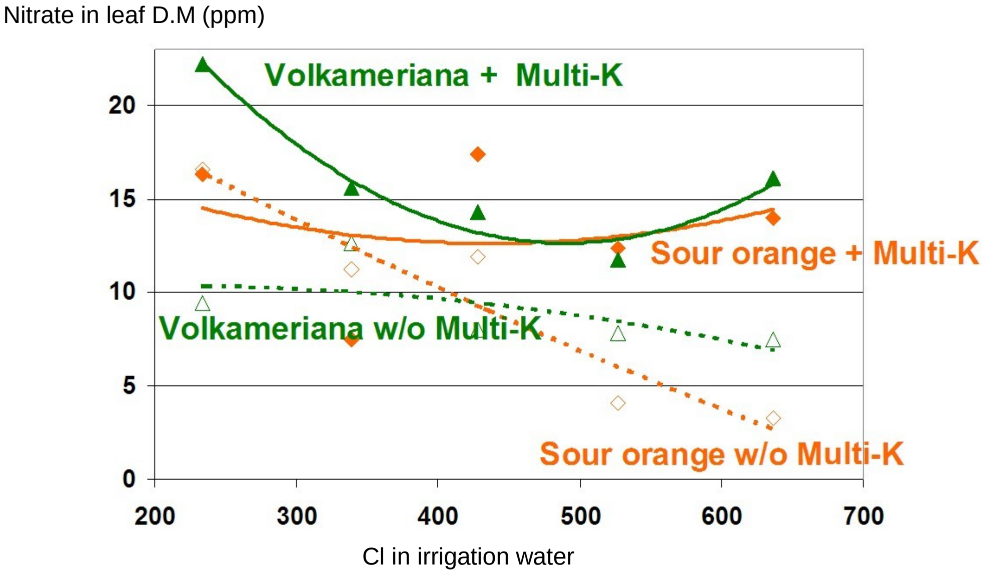


Figure 37: Multi-K® potassium nitrate increases nitrate content in citrus leaves under saline conditions.
Multi-K® treatment: constant concentration of 200ppm in the irrigation water.



High sodium level in the soil damages its particles structure and reduces water penetration. High sodium competes with potassium uptake, leading to potassium deficiency and upset tree nutrition. Correcting the salinity often restores normal potassium nutrition. When applying potassium fertilizer in saline areas, Multi-K® (potassium nitrate - KNO_3) should be used and not potassium chloride (muriate of potash). This is an effective way to minimize the salinity problem since the cation K^+ in Multi-K®, due to the antagonistic effect, will successfully suppress the uptake of sodium (Na^+) and increase the K^+ in leaves (Fig. 38-39) and in results, Multi-K® increases yield (Fig. 40).

Figure 38: Multi-K® potassium nitrate reduces Sodium (Na) content in citrus leaves under saline conditions. Multi-K® treatment: constant concentration of 200ppm in the irrigation water.

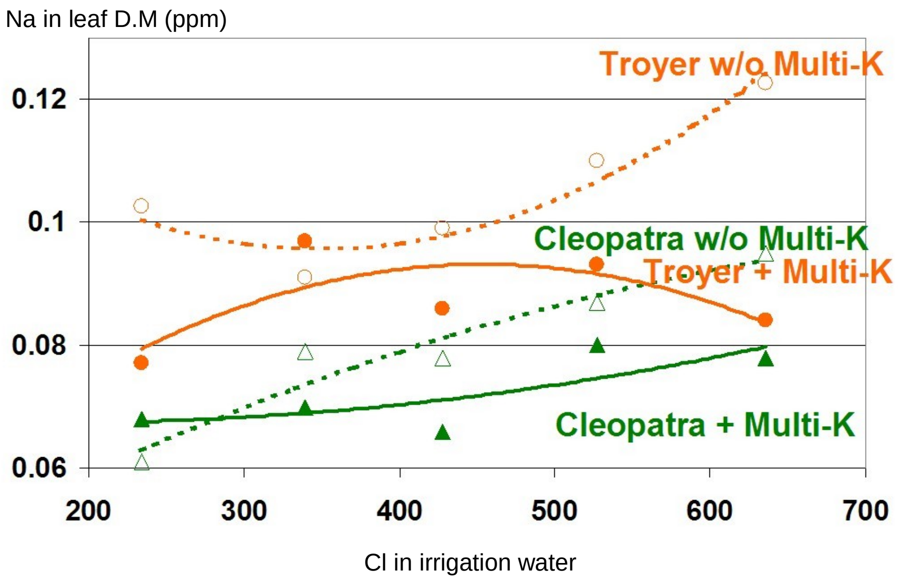


Figure 39: Multi-K® potassium nitrate increases K content in citrus leaves under saline conditions. Multi-K® treatment: constant concentration of 200 ppm in the irrigation water.

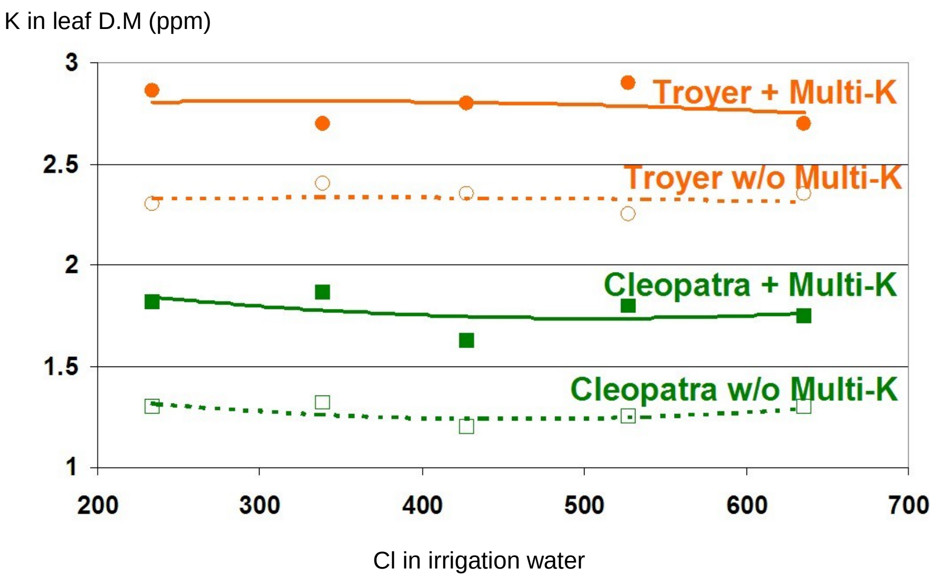
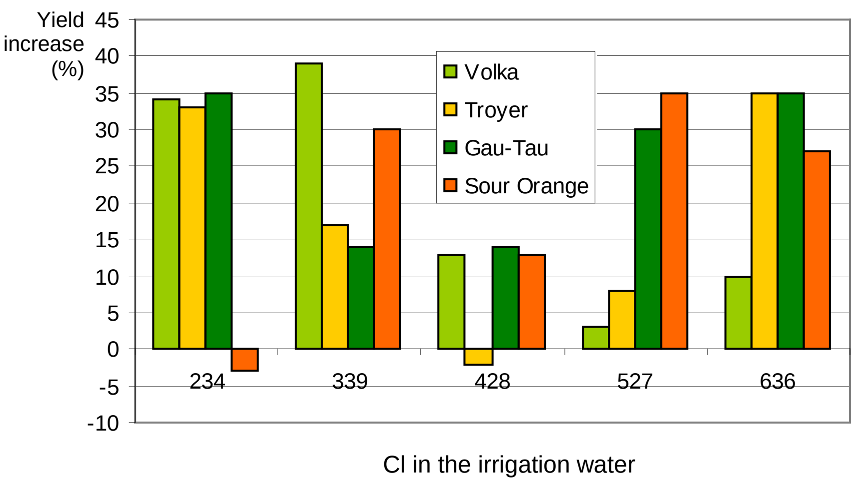


Figure 40: The Effect of Multi-K® potassium nitrate on the yield of citrus under saline conditions



2.4.2 Salt injury

Many salinity-induced symptoms are similar to drought stress symptoms, including reduced root growth, decreased flowering, smaller leaf size, and impaired shoot growth. These can occur prior to more easily observed ion toxicity symptoms on foliage. Chloride toxicity, consisting of burned necrotic or dry appearing edges of leaves, is one of the most common visible salt injury symptoms. Actual sodium toxicity symptoms can seldom be identified, but may be associated with the overall leaf "bronzing" (Fig. 41) and leaf drop characteristic of salt injury. Slightly different symptomology may occur depending on whether injury is due to root uptake or foliage contact. Excessive fertilizer applications, highly saline irrigation water, and storm-driven ocean sprays can all result in salinity-induced phytotoxic symptoms.

Figure 41 a-b: Salt injury

2.4.3 Copper toxicity

Symptoms can include thinning tree canopies, retarded growth and foliage with iron deficiency symptoms. Feeder roots may also become darkened, and show restricted growth. When extractable copper exceeds 100 pounds per acre, (1.12 kg/ha) trees may begin to decline. Old citrus land should be checked for soil copper before replanting. High soil copper levels may be ameliorated by liming to pH 6.5. The rootstock Swingle citrumelo is known to be quite susceptible to high soil copper.

2.4.4 Boron toxicity

Early stages of boron toxicity usually appear as a leaf tip yellowing or mottling (Fig. 42). In severe cases, gum spots appear on lower leaf surfaces (Fig. 43) with leaf drop occurring prematurely. Severe symptoms can include twig dieback .

Figure 42: leaves showing the signs of boron toxicity

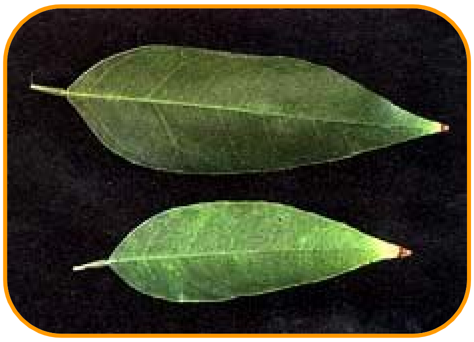


Figure 43: Gumming on underside of leaf

Figure 44: Necrosis at the tips and chlorosis beginning between the veins of Valencia orange leaves due to excessive boron.

High boron level in the irrigation water or in the soil may be problematic for growing citrus. Only in cases where the soil is the source of high boron, leaching irrigations and improved drainage will control the problem.
Rootstocks and scions differ in their susceptibility to boron toxicity. Citrus on rough lemon stock are more affected than those on sweet orange or *Poncirus trifoliata* rootstock. Lemons are the most susceptible scion, followed by mandarins, grapefruit and oranges.

2.4.5 Manganese toxicity

Manganese toxicity symptoms are occasionally found in citrus growing in very acid soils (usually below pH 5.0). The soil may be naturally acidic or have become acidic through continued heavy applications of strongly acidifying fertilizers, particularly ammonium sulfate.
Yellowing around the outer part of the leaves, especially of the older leaves, is the most characteristic effect of manganese toxicity in lemons. The yellowing is very bright and is described as 'yellow-top' (Fig. 45). Affected oranges and mandarins develop dark brown spots 3-5 mm in diameter, scattered over the leaves (tar spotting) (Fig. 46).

Figure 45: Manganese toxicity in lemons

Figure 46: Manganese toxicity signs on orange leaf

Toxicity is more common in loamy soil than in sands. Damp, poorly drained soil encourages the build-up of soluble manganese. Lemons, oranges, mandarins and grapefruits are all affected. Trees on *P. trifoliata* rootstock are affected worst, but the problem is also found in trees on rough lemon stock. Applications of Multi-K® potassium nitrate, whenever K fertilization is required, help to increase the soil pH and may help to prevent the manganese toxicity phenomena.

2.4.6 Biuret toxicity

Biuret is an impurity in urea fertilizer, which may be avoided using only guaranteed low-biuret urea products, particularly for foliar sprays. Leaf symptoms appear as irregular, yellowish-green interveinal chlorotic areas appearing first at leaf tips and spreading over the entire area of the leaf surface (Fig. 47). As severity increases, only the midribs and parts of the major veins remain green.

Figure 47: Lemon leaves with signs of biuret toxicity

3. Fertilization recommendations

The recommendations appearing in this document should be regarded as a general guide only. The exact fertilization program should be determined according to the specific crop needs, soil and water conditions, cultivar, and the grower's experience. For detailed recommendations, consult a local Haifa representative.

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3.1 Many benefits with Haifa quality fertilizers

Either soil application, fertigation or foliar treatments, Haifa provides quality products to benefit of any citrus grower.

Soil application

Multi-K® in prilled form, can be applied manually or by fertilizer spreader, a source of nitrogen in nitrate (NO3-) form and chlorine free potassium. Prevents salinity injuries and is quickly up-taken by tree roots.

Multicote® Agri most suitable when labor is not available or affordable, or where leaching of plant nutrients may occur, this control release fertilizer (CRF) is an ideal solution.

Nutrigation™ (fertigation)

Multi-K®, Poly-Feed®, Haifa MAP and **Haifa MKP** are water soluble fertilizers, containing major macro and minor plant nutrients. Due to the compatibility and the solubility of these fertilizers, can be fertigated in the most effective way and with most beneficial results.

Foliar applications:

Haifa Bonus affects the external and internal fruit quality: increases size and weight, prevents creasing and splitting, improves soluble solids and vitamin C content. In addition, correct quickly and effectively plant nutrient deficiencies.

Tank mix of **Haifa Bonus** with plant growth regulators, improves their functions.

In addition to nutritional functions, **Haifa Bonus** suppresses scale population, like Floridian Wax Scale, an environmental friendly and economical treatment.

Poly-Feed® available in many N-P-K ratios to deal with an effective way to prevent and to cure plant nutrient deficiencies.

Magnisal® will cure in a very quick and effective way magnesium (Mg) deficiencies.

3.2 Summary of recommended applications with Haifa fertilizers*

Table 10: Summary of recommended applications with Haifa fertilizers*

A – Leaf analysis determining fertilization requirements			
Leaf analysis	N (%)	P (%)	K (%)
Deficient	<2.2	<0.09	<0.7
Low	2.2-2.4	0.09-0.11	0.7-1.1
Optimum	2.5-2.7	0.12-0.16	1.2-1.7
High	2.8-3.0	0.17-0.30	1.8-2.4
Excess	>3.0	>.30	>2.4

* For detailed recommendations, refer to the relevant paragraph in the following chapters

B - Plant nutrients requirement			
Growing stage	**First yield**	**Production 70%**	**Full production**
Expected Yield (T/ha)	**21 - 8**	**49 - 18**	**70 - 25**
N	47 - 97	79 - 192	95 - 247
P_2O_5	63 - 75	74 - 100	77 - 116
K_2O	45 - 105	83 - 221	102 - 293
CaO	20 - 39	33 - 74	38 - 92
MgO	6 - 12	12 - 25	13 - 31

* For detailed recommendations, refer to the relevant paragraph in the following chapters.

C - Soil application	Young trees (g/tree/year)		
	Age of tree	**N rate**	**Rate of Multi-K®**
N	Year 1	70 – 140	500 – 1000
	Year 2	140 – 280	1000 – 2000
	Year 3	280 – 420	2000 – 3200
K	Year 1	70 – 140	150 - 300
	Year 2	140 – 280	300 – 600
	Year 3	280 – 420	600 – 900
	4-7 years (kg/ha/year)		
		N rate	**Rate of Multi-K®**
N	Grapefruit	120 – 160	900 – 1200
	Orange, Tangelo or Tangerine	120 – 200	900 – 1500
K	Grapefruit	120 – 160	260 – 350
	Orange, Tangelo or Tangerine	120 – 200	260 – 430

	Eight years and older (kg/ha/year)		
		N rate	**Rate of Multi-K®**
N	Oranges	140-250	1000 – 1900 kg
	Grapefruit	120-160	900 -1200 Kg
	Tangerine/Tangelo	120-300	900 – 2300 Kg
K	Oranges:	140-250	300 – 540
	Grapefruit	120-160	260 – 350
	Tangerine/Tangelo	120-300	260 –650
CRF	**Multicote® Agri** 16-5-12	In planting hole	300 – 500 g/tree
		Non-bearing trees	250 – 600 g/tree
		Bearing trees	1 – 1.5 kg/tree

* For detailed recommendations, refer to the relevant paragraph in the following chapters.

D - Nutrigation™				
	Young trees			
Age (yr)	N	Urea	**Multi-K®**	Annual **Multi-K®**
	Daily supply (g/tree)			Kg/tree
1	1.5 - 2.5	2.3 - 4.0	3.2 - 5.4	0.768 - 1.296
2	2.5 - 3.5	4.0 - 5.4	5.4 - 7.6	1.296 - 1.824
3	4.0 - 4.5	6.2 - 7.0	8.7 - 9.8	2.088 - 2.352
4	4.5 - 5.0	7.0 - 10.5	9.8 - 10.8	2.352 - 2.592
	Bearing trees (Kg/ha)			
		N	**P_2O_5**	**K_2O**
		200-300	60	180-300
Fertilizer	Urea	400-600		
	Haifa MAP		100	
	Multi-K®			400-650
	Bearing Trees - higher yield (Kg/ha)			
		N	**P_2O_5**	**K_2O**
		650 - 950	250	650 - 1000
Fertilizer	Urea	950 - 1250		
	Haifa MAP		400	
	Multi-K®			1400 - 2000

* For detailed recommendations, refer to the relevant paragraph in the following chapters.

E - Proportional Nutrigation™ (ppm)	
N (20-30% as NH_4^+)	35
P (as orthophosphate*)	10
P_2O_5	22.7
K	25
K_2O	30.1

* For detailed recommendations, refer to the relevant paragraph in the following chapters.

F - Foliar feeding -Young trees	
Poly-Feed®	2%

* For detailed recommendations, refer to the relevant paragraph in the following chapters.

G - Foliar feeding			
		Product	Concentration
Correct deficiency	K	Haifa Bonus	4%
	Mg	Magnisal®	1.4%

* For detailed recommendations, refer to the relevant paragraph in the following chapters.

H – Foliar treatments with Haifa Bonus			
Yield & Quality	Parameter	Concentration	No. of Applications
External fruit quality	Increases size	2 – 6 %	2 - 4
	Increases fruit weight	2 – 6 %	2 - 4
	Improves rind color	2 – 6 %	2 - 4
Rind Disorders	Reduces creasing	2 – 6 %	2 - 4
	Reduces splitting	2 – 6 %	2 - 4
Internal juice quality	Increases juice content	2 – 6 %	2 - 4
	Increases of soluble solids	2 – 6 %	2 - 4
	Increases of acid	2 – 6 %	2 - 4
	Increases vitamin C	2 – 6 %	2 - 4
Floridian Wax Scale	Suppression	4%	1 - 2
Growth regulator	Fruit size & productivity	4%	Growth regulators
			2,4-D + 2,4-DP
			NAA
			TPA

* For detailed recommendations, refer to the relevant paragraph in the following chapters.

3.3 Plant nutrients requirements

The tree age and the expected yield are two important parameters in determining the required plant nutrients (Table 11).

Table 11: Required rates of macro and secondary plant nutrients according to growing stages and expected yield .

Growing stage	First yield	Full production	Production 70%
Expected Yield (T/ha(	**21 - 8**	**70 - 25**	**49 - 18**
N	47 - 97	95 - 247	79 -1 92
P_2O_5	63 - 75	77 - 116	74 - 100
K_2O	45 - 105	102 - 293	83 - 221
CaO	20 - 39	38 - 92	33 - 74
MgO	6 - 12	13 - 31	12 - 25

3.4 Soil analysis

This is useful for measuring pH, available P and certain exchangeable cations, notably Ca and Mg.

Table 12: A standard soil test, using Mehlich-1 extractant, interpretation and phosphorus recommendations for commercial citrus orchards, 1-3 years of age.

Soil test Phosphorus, ppm	**0 - 10**	**10 - 15**	**16 - 30**	**31 - 60**
Interpretive Classes	Very Low	Low	Medium	High
Recommendation for P_2O_5 application (g/tree)	Apply at 100% of the N rate	Apply at 75% of the N rate	Apply at 50% of the N rate	0

Application of high rate of magnesium (Mg) fertilizers, may suppress the uptake of potassium (K) due to their cationic competition.

Table 13: The standard Mehlich-1 soil test interpretations and magnesium recommendations for commercial citrus orchards.

Soil Test Magnesium, (ppm)	**< 15**	**15 - 30**	**> 30**
Interpretive Classes	Very low - Low	Medium	High - Very High
Recommendation	Apply Mg fertilizer with MgO at 20% of the N rate	Apply Mg fertilizer with MgO at 20% of the N rate	No Mg recommended

However, because citrus trees are grown on a wide range of soil types, it would be difficult to establish standards for all soils. They are therefore usually developed for certain soil types in a given region.
It is usually more difficult to assess the N and K status in the soil because both these elements are subject to leaching, especially in humid regions.

3.5 Plant analysis data

Leaf analysis is an essential tool to determine the required plant nutrients (Table 14). According to leaf analysis results, the fertilization rates and the correct ratio of plant nutrients can help to schedule the fertilization program.

Table 14: Leaf analysis standards for mature, bearing citrus trees based on 4 to 6-month-old, spring-cycle leaves from non-fruiting terminals.

Element	Deficient	Low	Optimum	High	Excess
N (%)	<2.2	2.2-2.4	2.5-2.7	2.8-3.0	>3.0
P (%)	<0.09	0.09-0.11	0.12-0.16	0.17-0.30	>.30
K (%)	<0.7	0.7-1.1	1.2-1.7	1.8-2.4	>2.4
Ca (%)	<1.5	1.5-2.9	3.0-4.9	5.0-7.0	>7.0
Mg (%)	<0.20	0.20-0.29	0.30-0.49	0.50-0.70	>0.70
Cl (%)	?	?	0.05-0.10	0.11-0.25	>.25
Na (%)	-	-	-	0.15-0.25	>.25
Mn (ppm)	<17	18-24	25-100	101-300	>300
Zn (ppm)	<17	18-24	25-100	101-300	>300
Cu (ppm)	<3	3-4	5-16	17-20	>20
Fe (ppm)	<35	35-59	60-120	121-200	>200
B (ppm)	<20	20-35	36-100	101--200	>200
Mo (ppm)	<0.05	0.06-0.09	0.10-1.0	2.0-5.0	>5.0

3.6 Nitrogen

The form of a nitrogen, either ammonium (NH_4^+), nitrate (NO_3^-) or amide (NH_2), plays an important role when choosing the right fertilizer for Nutrigation™ of citrus trees.
Nitrate-nitrogen is a preferable source of nitrogen as it suppresses the uptake of chloride (Cl^-) and at the same time promotes the uptake of cations, such as potassium (K^+), magnesium (Mg^{2+}) and Calcium (Ca^{2+}). In addition, the nitrate form of nitrogen increases the pH of soil solution near the root system, especially important in acidic soils.

The nitrogen in Multi-K® (potassium nitrate, KNO_3) is entirely in nitrate form, which makes it a suitable fertilizer for Nutrtigation™.

Table 15: Nitrogen requirements and recommendations for the first three years after planting

Age of tree	N rate (g/tree/year)	Rate of Multi-K® (g/tree/year) as a single N source*
Year 1	70 – 140	500 – 1000
Year 2	140 – 280	1000 –2000
Year 3	280 – 420	2000 –3200

* Other water-soluble N fertilizer may be added and Multi-K® rate should be reduced accordingly.

Table 16: Nitrogen requirements and recommendations for trees aged 4-7 years, by variety

Variety	N rate (kg/ha/year)	Rate of Multi-K®/ (kg/ha/year) as a single N source*
Grapefruit	120 -160	900 –1200 kg Multi-K® / Ha
Orange, Tangelo or Tangerine	120 – 200	900–1500 kg Multi-K® / Ha

* Other water-soluble N fertilizer may be added and Multi-K® rate should be reduced accordingly.

Table 17: Nitrogen requirements and recommendations for trees eight years and older

Variety	N rate (kg/ha/year)	Rate of Multi-K®/ (kg/ha/year) as a single N source*
Oranges	140-250	1000 – 1900 kg
Grapefruit	120-160	900 -1200 Kg
Tangerine/Tangelo	120-300	900 – 2300 Kg

* Other water-soluble N fertilizer may be added and Multi-K® rate should be reduced accordingly.

3.7 Phosphorus

Table 18: Test interpretations and phosphorus recommendations for commercial citrus orchards, ages 4 and above.

P level in leaf tissue	Soil test P level	P recommendation
High or Very High	Soil test P not applicable	0 Kg of P_2O_5 for 12 months until re-evaluation
Optimum	Sufficient	0 Kg of P_2O_5 for 12 months until re-evaluation
Optimum	Less than sufficient	8 Kg P_2O_5/ha for every 9,500 kg of fruit produced per ha during one year
Low	Less than sufficient	12 Kg P_2O_5/ha for every 9,500 kg of fruit produced per ha during one year
Deficient	Less than sufficient	16 Kg P_2O_5/ha for every 9,500 kg of fruit produced per ha during one year

3.8 Potassium

Potassium recommendations also depend on the age of citrus trees. During the first 3 years after planting, K_2O should be applied at the same rate as N (g K_2O/tree). For orchard ages of 4 years and above, K_2O should be applied at the same rate as N (in Kg K_2O/ha).

Table 19: K recommendations for the **first three years** of orchard-age

Age of tree	Rate of K_2O (g/tree)	Rate of **Multi-K®** (g/tree)
Year 1	70 – 140	150 - 300
Year 2	140 – 280	300 –600
Year 3	280 – 420	600 –900

Table 20: K requirements and recommendations for trees aged **4-7 years,**

Variety	Rate of K_2O (kg/ha/year)	Rate of **Multi-K®** (kg/ha/year)
Grapefruit	120 -160	260 –350
Orange, Tangelo or Tangerine	120 – 200	260 –430

Table 21: K requirements and recommendations for trees **eight years and older**

Variety	Rate of K_2O (kg/ha/year)	Rate of Multi-K® (kg/ha/year)
Oranges:	140-250	300 –540
Grapefruit	120-160	260 -350
Tangerine/Tangelo	120-300	260 –650

3.9 Nutrigation™ (fertigation)

Application of water-soluble fertilizers through the irrigation system is the optimal method for providing balanced plant nutrition throughout the growth season. A balanced Nutrigation™ regime ensures that essential nutrients are placed precisely at the site of intensive root activity and are available in exactly the right quantity - *when plants need them.*

3.9.1 Nutrigation™ recommendations for young trees

- Soil type: Light to medium
- 240 irrigation (application) days per year. If more application days, calculated daily rates should be reduced, accordingly
- Rates are based on N: K_2O ratio 1: 1

Table 22: Nutrigation™ recommendations for young trees

Year	N	Urea	Multi-K®	Annual Multi-K®
	Daily supply (g/tree)*			Kg/tree
1	1.5 - 2.5	2.3 - 4.0	3.2 - 5.4	0.768 - 1.296
2	2.5 - 3.5	4.0 - 5.4	5.4 - 7.6	1.296 - 1.824
3	4.0 - 4.5	6.2 - 7.0	8.7 - 9.8	2.088 - 2.352
4	4.5 - 5.0	7.0 - 10.5	9.8 - 10.8	2.352 - 2.592

* In fertile soils and irrigated water with high content of plant nutrients, rates of fertilizers should be reduced, accordingly.

Table 23: Recommended applications of **Haifa MAP** (12-61-0) when soil test is not available

Year	P_2O_5	Haifa MAP	Haifa MAP
	(g/tree/day)	(g/tree/day)	(g/tree/year)*
1	0.5	0.8	192
2	1.0	1.6	384
3	1.5	2.4	576
4	2.0	3.2	768

* Estimated 240 irrigated days.

3.9.2 Nutrigation™ recommendation of bearing trees

- Soil type: light to medium
- Tree population: 400-600 trees/ha
- Expected yield: 40 t/ha

The recommended average rates of nutrients (Kg/ha):

N	P_2O_5	K_2O
200-300	60	180-300

Nitrogen: The recommended amount is based on the nitrogen consumption of 4-6 Kg N/ ton of fresh fruit. 75% of the entire amount of nitrogen should be applied from early spring to the mid-summer. It is recommended to split this amount of nitrogen and to apply it proportionally in each one of the irrigation cycles.
The rest 25% can be applied in autumn, after color breaking, or as post-harvest fertilization.

Phosphorus: One or two applications at the beginning of spring.

Potassium: It is recommended to divide the entire amount of potassium and to apply it proportionally in each one of the irrigation cycles from early spring to early summer irrigations.

Nutrigation™ Schedule:

Table 24: Nutrigation™ schedule on bearing trees

Fertilizer	Application time	No. of applications	Total amount
Multi-K®	Spring to early summer	Weekly	400-650 Kg/ha
Urea	During the season	Weekly	400-600 Kg/ha
Haifa MAP	Spring	1-2	100 Kg/ha

Recommendations for Bearing Trees (higher yield)

- Soil type: light to medium
- Plant population: 440 trees / ha
- Expected yield: 60 ton / ha

The recommended average rates of nutrients (Kg/ha):

N	P_2O_5	K_2O
650 - 950	250	650 - 1000

	Kg. / ha	N	P_2O_5	K_2O
Urea	950 - 1250	430 - 570	0	0
Haifa MAP	400	50	240	0
Multi-K®	1400 - 2000	175 - 280	0	650 - 1000

Table 25: Nutrigation™ schedule of total plant nutrients per seasonal application

Fertilizer	kg / ha	kg/ha		
		N	P_2O_5	K_2O
First irrigation (spring)				
Multi-K®*	400 - 700	52 - 91		184 - 322
Urea*	300 - 500	138 - 230		
Haifa MAP**	150	18	92	
Spring - Summer				
Multi-K®*	650 - 900	85 - 117		299 - 414
Urea*	600 - 950	276 - 437		
Haifa MAP**	100	12	61	
Late Summer - Fall* (Last irrigation)				
Multi-K®*	350 - 500	45.5 - 65		161 - 230
Haifa MAP**	150	18	92	
Total		644 - 988	244	644 - 966

* Split into low rates and applied weekly ; ** Split into 1-2 applications

In case of magnesium deficiency, it is recommended to spray with 2% **Magnisal®** (Haifa's magnesium nitrate product) when the leaves of the early spring flush have reached 2/3 of their final size. This Nutrigation™ program should be adjusted according to leaf analysis data.

3.9.3 Proportional Nutrigation™

Proportional Nutrigation™, (constant concentrations of plant nutrients during the entire irrigation session) is a beneficial tool, mainly when growing on sandy soils (Table 26).

Table 26: Proportional Nutrigation™

Nutrient	mg/l (ppm)
N (20-30% as NH_4^+)	35
P (as orthophosphate*)	10
P_2O_5	22.7
K	25
K_2O	30.1
Ca	20
CaO	28.2
Mg	10
MgO	16.7
S	13
SO_3	32.5

Nutrient	mg/l (ppm)
Cu (as chelates)	0.012
Fe (as EDTA chelate)	0.088
Mn (as chelate)	0.088
Zn (as chelate)	0.056
Mo	0.0006
B	0.088

* P in orthophosphate form serves as a buffer.

3.9.4 Nutrigation™ practice in Israel

Non-bearing citrus trees

Table 27: Recommended rates of N, P and K, on young – non-bearing citrus trees:

Age of tree	N-P-K g/tree			Actual fertilizers		
	N g/tree	P_2O_5 g/tree	K_2O g/tree	Multi-K®	Urea	Haifa MAP
First year	0.4	0.2	0.4	0.9	0.3	0.4
Second year	0.8	0.4	0.8	1.8	0.6	0.7
Third year	1.6	0.8	1.6	3.5	1.2	1.3
Forth year	3.2	1.6	3.2	7.0	2.4	2.6

When proportional fertigation is used, the concentration of N, the irrigated water in non-bearing orchard should not exceed 200 ppm (200 g N in 1000 L water).

In fruit bearing orchards grow where leaf analysis is not available, it is recommended to apply 200 kg N /ha/yr, 180 Kg K_2O/ha/yr and once in three years 60 Kg P_2O_5/ha.

Applications of potassium may vary according to soil texture; in light texture soils, low rates of phosphorus in each fertigation may be added, similarly to N, while in heavier texture soils higher rates of P may be applied once a week.

Bearing citrus trees

Apply N throughout the irrigation period according to the harvesting time of the fertigated variety. Varieties that are having color breaking difficulties, it is recommended to complete the N fertigation in mid-summer. When proportional fertigation is used, the concentration of N, the irrigated water bearing orchard, should not exceed 50 ppm N (50 g N in 1000 L water).

Phosphorus should be applied, as needed, during the entire fertigated period in equal rates. If orchard is not fertigated, phosphorous should be applied in one portion in either spring or fall.

Applications of potassium may vary according to soil texture; in light texture soils, low rates of phosphorus in each fertigation may be added, similarly to N, while in heavier texture soils higher rates of P may be applied; once a month.

Recommendations according to leaf analysis

Table 28: Recommended potassium application rates according to leaf analysis, for oranges, (Shamuti, Washington navels, Valencia), lemons and tangerines:

K level in leaves (% of dry weight)	Low	Optimum	Excess
	Less than 0.45%	0.45% - 1%	Above 1%
Recommended rate of K_2O kg/ha	300	180	0

<u>Table 29</u>: Recommended potassium application rates according to leaf analysis, for grapefruits:

K level in leaves (% of dry weight)	Low	Optimum	Excess
	Less than 0.35%	**0.36% - 0.75%**	**Above 0.75%**
Recommended rate of K_2O kg/ha	300	180	0

Potassium: should be applied in the same rates and methods as nitrogen.

<u>Table 30</u>: Recommended phosphorous application rates according to leaf analysis, for oranges, (Shamuti, Washington navels), lemons and tangerines:

P level in leaves (%) in leaves	Low	Optimum	Excess
	Less than 0.35%	**0.36% - 0.75%**	**Above 0.75%**
Recommended rate of P_2O_5 kg/ha	120	60	0

<u>Table 31</u>: Recommended phosphorous application rates according to leaf analysis, for grapefruits and Valencia oranges:

P level in leaves (%) in leaves	Low	Optimum	Excess
	Less than 0.03%	**0.031%-0.040%**	**Above 0.041%**
Recommended rate of P_2O_5 kg/ha	120	60	0

Phosphorous: When drip irrigation is practiced, it is recommended to apply the phosphorous as a full-soluble product, such as Haifa MAP or Haifa MKP, at a constant concentration, during the entire irrigation season

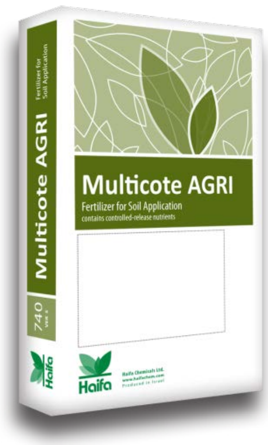
When leaf analysis is unavailable, it is recommended to apply 200 kg/ha of nitrogen, 180 kg /ha of K_2O and once every three years, 60 kg/ha of P_2O_5.

Nutrigation™ with recycled water: this kind of water may contain substantial quantities of plant nutrients. Therefore, it is recommend analyzing the water in order to determine the available plant nutrient and to use the leaf analysis results as a guidance criterion for the real application of the fertilizers

3.10 Multicote® Agri controlled release fertilizers

There are two main situations in which the use of **Multicote® Agri** products are recommended:

1) In the planting hole: It is recommended to apply **Multicote® Agri** in the planting hole, to ensure balanced and adequate plant nutrients that are essential during the root development stage and the initial growth. This is recommended both in the nursery, when the seedling is transferred to the growth pot, and when the young plant is transplanted to the new plantation.



2) In sandy soils and high precipitation conditions: As a standard crop nutrition management, in order to minimize leaching problems and yet to feed the citrus trees with all essential plants nutrients, the grower has a choice of several longevities of **Multicote® Agri** to suit crop needs according to local growing conditions.

Multicote® Agri applications:
To select the right **Multicote® Agri** formula and to set application rates, some guidelines have to be followed:

- Release longevity should consider soil temperatures. As the release rate increases with temperature, higher temperatures require formula with extended longevity. Note that the declared longevity refers to release at 21°C
- Under heavy rainfall or intensive irrigation, formula with higher percentage of coated nutrients is required.
- In any case, the percentage of coated nitrogen must exceed the minimum of 25% of the total N in the product.
- The total rates of nutrients should consider
  - Theoretical needs based on removal by the crop+expected losses
  - Required/expected yield level
  - Farmer's common practice and experience

Under most conditions, **Multicote® Agri** enables reduction of 10-20% in application rates as compared to conventional fertilization.
Please consult Haifa agronomist to customize **Multicote® Agri** fertilization program to suit your needs.

3.11 Foliar nutrition

Foliar feeding is a fast and highly effective method of supplementing and enriching plant nutrients when needed. Foliar application of Haifa water soluble fertilizers provides needed plant nutrients for normal development of crops when absorption of nutrients from the soil is disturbed, precision-timed foliar sprays are also a fast-acting and effective method for treating nutrient deficiencies.

Foliar application of the correct nutrients in relatively low concentrations at critical stages in crop development contributes significantly to higher yields and improved quality.

Determine safe foliar applied rate:
To verify the safe rate under local conditions, it is advisable to spray recommended rate on a few plants. After 3-4 days check the tested plants for scorching symptoms.

Preparation of tank-mix:
Dissolve Haifa water-soluble fertilizes in about half of the tank volume, and add to the spray tank. When applying together with crop-protection agents, addition of wetting agents is not necessary. To ensure compatibility of tank-mix components, a small-scale test should be performed prior to actual application.

Table 32: Haifa water-soluble fertilizers for foliar application

Fertilizer	Curing Treatment
Haifa Bonus	Potassium deficiency
Haifa MAP	Phosphorus deficiency
Haifa MKP	Phosphorus and potassium deficiency
Magnisal®	Magnesium deficiency
Poly-Feed®	N-P-K and micronutrients deficiency
Haifa Micro®	Micronutrients deficiencies

3.11.1 Haifa Bonus increases yields and enlarges fruits

Foliar treatments with Haifa Bonus proved to increase yield of many citrus species and varieties as well as increases fruit size, an important commercial parameter (Tables 33-35).

Table 33: Effect of **Haifa Bonus** spray on size, yield and N & K levels in leaves of "Marsh" grapefruit.

Treatment	Yield Boxes / tree	Fruit size Fruit / box	Content in dry leaves (%)	
			N	K
Unsprayed	3.88	69.4	2.56	2.56
Sprayed* with Haifa Bonus	4.38	65.7	2.68	2.68

* 3 % spray solution X 3 applications (April, June, and November)

Table 34: Effect of **Haifa Bonus** on Yield and Fruit Size of "Valencia" oranges

Treatment	Yield		Fruit size Fruit / box
	Boxes / tree	Fruits / tree	
Unsprayed	7.54	976	130
Sprayed* with Haifa Bonus	9.45	1135	120

* 5 % spray solution.

Table 35: Effect of **Haifa Bonus** sprays on fruit size of "Shamuti" oranges

Treatment	Yield kg / tree	Fruit Size			
		Small	Medium	Large	Jumbo
		------------- % -------------			
Control	102.8	63.94	19.39	14.26	2.4
4% Haifa Bonus +18 ppm 2,4-D (1 spray)	125.3	38.75	22.17	31.24	7.83
4% Haifa Bonus +18 ppm 2,4-D (2 sprays)	122.63	30.22	22.42	33.52	13.36
4% Haifa Bonus + 200 ppm NAA	79.1	18.26	12.66	40.66	28.41
4% Haifa Bonus + 300 ppm NAA	62.6	33.21	18.19	31.80	16.77

Foliar treatments with Haifa Bonus not only increases yield fruit size, but also reduces fruit splitting, a problem that may cause a severe reduction in marketable fruits (Tab. 11 – 13).

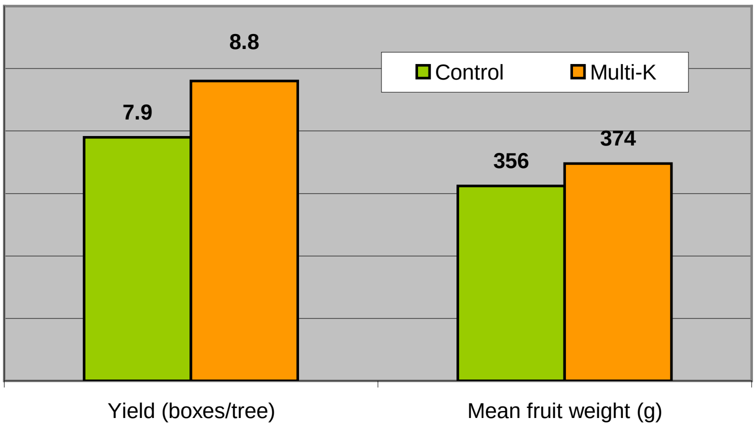
Table 36: Effect of **Haifa Bonus** spray on reducing splitting in "Nova" oranges

Treatment	No. of treatments	Fruit split (%)
Control		62.2
5% Haifa Bonus	1	55.5
5% Haifa Bonus	2	40.7
5% Haifa Bonus	3	41.1
5% Haifa Bonus + 20 ppm 2,4-D	1	35.4
5% Haifa Bonus + 20 ppm 2,4-D	2	19.6
5% Haifa Bonus + 20 ppm 2,4-D	3	20.1

Table 37: Effect of **Haifa Bonus** on "Nova" mandarins - R. Lavon (1992)

Treatment	Yield (kg/tree)	Fruits/tree	Mean weight of fruit (g)	Split (%)
Unsprayed	35 b	404 b	94 a	52 a
Ca-Nitrate 2%	43 ab	433 a	99 a	40 ab
Haifa Bonus 3%	57 a	539 a	109 a	35 b
Ca-Nitrate 2%+ Haifa Bonus 3%	49 ab	477 a	104 a	35 b

Figure 48: The Effect of **Haifa Bonus** on Yield & Fruit Size of Ruby-Red Grapefruit



Haifa Bonus also reduces the fruit drop and affects the fruit quality (Tables 38-39).

Table 38: Effect of **Haifa Bonus** on K level in leaves and fruit drop of "Valencia" oranges

Treatment	K in Leaves (%)	Fruit Drop (fruits/tree)	Yield (box/tree)
Unsprayed	0.47	193	1.14
Haifa Bonus 4%	1.30	33	5.39

Table 39: Effect of **Haifa Bonus** spray on "Lisbon" Lemons (USA)

Treatment	K concentration (%)		Acid in juice (% w/w))	Fruit Color Rating
	Leaf	Peel		
Unsprayed	0.39	0.51	6.40	1.72
Haifa Bonus spray*	0.50	0.70	6.88	1.88

* 3 % spray solution X 3 applications (April, June, and November)

3.11.2 Foliar feeding on young trees

Table 40: Foliar feeding with **Poly-Feed®** on young citrus trees to stimulate growth

Period	Frequency	Product	Spray concentration
May	Biweekly	**Poly-Feed®***	2%
July-August	Biweekly	**Poly-Feed®***	2%
September-October	Monthly	**Haifa Bonus** + phosphoric acid	4% + 0.1%

* add surfactant

Table 41: Foliar feeding to correct deficiencies

Plant Nutrient	Period	Product	Spray concentration
Magnesium (Mg)	Spring, when leaves are 2/3 of their final size	**Magnisal®**	1.4 %
Potassium (K)	May-August, 1-2 applications	**Haifa Bonus**	4 %

3.11.3 Foliar feeding prevents creasing and splitting, and improves fruit quality

For many years, foliar applications of Haifa Bonus fertilizer proved to be an efficient treatment to reduce creasing in oranges (Tab. Xx).

Table 42: Foliar application of Haifa Bonus increases leaf K and reduces creasing in "Valencia" oranges

Treatment	Leaf K (%)		Creased fruits (%)	Severity index
	Before spray	After spray		
Unsprayed	0.46	0.34	42.6	100
Sprayed* with Haifa Bonus	0.45	0.54	27.2	64

* 5 % spray solution.

Based on research results, the recommended treatment to reduce creasing is, to apply 4%-6% **Haifa Bonus**: 1st application on Mid June (after June drop), and 2nd application one month later (Table 43).

Table 43: Recommended foliar treatments with **Haifa Bonus**

Treatment purpose	Application rate (kg/ha)	Conc. (%)	Spray vol. (liter/ha)	Timing	No. of sprays
Nutrition	100-240	4-6	2500-4000	Spring	1-3
Increase fruit size				Spring - Summer	1-2
Reduce fruit drop				After fruit-set	2-4
Reduce splitting and creasing				Spring - Summer	3-4
Suppress Floridian Wax Scale				Spring - Summer	1-2

Table 44: Growth regulators treatments, affecting fruit size and tree productivity, by variety.

Varieties	Time of Treatment	Growth Regulator	Additives to growth regulators
Shamuti, Valencia Washington	End May - early June, Fruitlets 15-20 mm in diameter	2,4-D 20-40 ppm 2,4-DP 50-60 ppm	Haifa Bonus 4-6%
Michal, Clementines, Murkot, Dennis	End May - early June, Fruitlets 8-12 mm in diameter	NAA 200-300 ppm	Haifa Bonus 4-6%
Michal, Murkot	Fruitlets 21-25 mm in diameter	TPA-3,5,6 10-15 ppm	Haifa Bonus 4-6%
Valencia Washington	Fruitlets 15-18 mm in diameter	2,4-DP 50-60 ppm	Haifa Bonus 4-6%
Red Grapefruit, White Grapefruit	Fruitlets 15-20 mm in diameter	NAA 300 ppm	Haifa Bonus 4%

Appendix I: Haifa specialty fertilizers

Pioneering Solutions

Haifa develops and produces **Potassium Nitrate** products, **Soluble Fertilizers** for Nutrigation™ and foliar sprays, and **Controlled-Release Fertilizers**. Haifa's Agriculture Solutions maximize yields from given inputs of land, water and plant nutrients for diverse farming practices. With innovative plant nutrition schemes and highly efficient application methods, Haifa's solutions provide balanced plant nutrition at precise dosing, composition and placing. This ultimately delivers maximum efficiency, optimal plant development and minimized losses to the environment.

Potassium Nitrate

Haifa's Potassium Nitrate products represent a unique source of potassium due to their nutritional value and contribution to plant's health and yields. Potassium Nitrate has distinctive chemical and physical properties that are beneficial to the environment. Haifa offers a wide range of potassium nitrate products for Nutrigation™, foliar sprays, side-dressing and controlled-release fertilization. Haifa's potassium nitrate products are marketed under the Multi-K® brand.

Multi-K® Products

Pure Multi-K®

Multi-K® Classic	Crystalline potassium nitrate (13-0-46)
Multi-K® Prills	Potassium nitrate prills (13-0-46)

Special Grades

Multi-K® GG	Greenhouse-grade potassium nitrate (13.5-0-46.2)
Multi-K® pHast	Low-pH potassium nitrate (13.5-0-46.2)
Multi-K® Top	Hydroponics-grade potassium nitrate (13.8-0-46.5)

Enriched Products

Multi-npK®	Enriched with phosphate; crystalline or prills
Multi-K® Mg	Enriched with magnesium; crystalline or prills
Multi-K® Zn	Enriched with zinc; crystalline
Multi-K® S	Enriched with sulfate; crystalline
Multi-K® B	Enriched with boron; crystalline or prills
Multi-K® ME	Enriched with magnesium and micronutrients; crystalline

Nutrigation™

Nutrigation™ (fertigation) delivers pure plant nutrients through the irrigation system, supplying essential nutrients precisely to the area of most intensive root activity. Haifa's well-balanced Nutrigation™ program provides the plant with their exact needs accordingly with seasonal changes. Decades of experience in production and application of specialty fertilizers for Nutrigation™ have made Haifa a leading company in this field. Haifa keeps constantly up to date with contemporary scientific and agricultural research, in order to continuously broaden its product line to better meet the requirements of crops and cropping environments.

HAIFA offers a wide range of water-soluble fertilizers for Nutrigation™. All products contain only pure plant nutrients and are free of sodium and chloride

Multi-K®	Comprehensive range of plain and enriched potassium nitrate products
Poly-Feed®	Soluble NPK fertilizers enriched with secondary and micro-nutrients
Haifa MAP	Mono-ammonium phosphate
Haifa MKP	Mono-potassium phosphate
Haifa Cal	Calcium nitrate
Magnisal®	Our original magnesium nitrate fertilizer
Haifa Micro	Chelated micronutrients
Haifa VitaPhos-K™	Precipitation-proof poly-phosphate for soilless Nutrigation™
Haifa ProteK	Systemic PK fertilizer

Foliar Feeding

Foliar Feeding provides fast, on-the-spot supplementary nutrition to ensure high, top quality yields and is an ideal feeding method under certain growth conditions in which absorption of nutrients from the soil is inefficient, or for use on short–term crops. Precision-timed foliar sprays are also a fast-acting and effective method for treating nutrient deficiencies. Foliar application of the correct nutrients in relatively low concentrations at critical stages in crop development contributes significantly to higher yields and improved quality. Haifa offers a selection of premium fertilizers for foliar application. Haifa offers a selection of fertilizers for foliar application:

Haifa Bonus High-K foliar formulas enriched with special adjuvants for better absorption and prolonged action
Poly-Feed® Foliar NPK formulas enriched with micronutrients specially designed to enhance the crop performance during specific growth stages
Magnisal®, **Haifa MAP**, **Haifa MKP**, **Haifa Cal** and **Haifa Micro** are also suitable for foliar application.

Controlled Release Nutrition

Multicote®, Haifa's range of Controlled Release Fertilizers includes products for agriculture, horticulture, ornamentals and turf. Multicote® products provide plants with balanced nutrition according to their growth needs throughout the growth cycle. Multicote® products enhance plant growth, improve nutrients use efficiency, save on labor and minimize environmental impact.

Single, pre-plant application controlled-release fertilizer can take care of the crop's nutritional requirements throughout the growth season. Controlled release fertilizers are designed to feed plants continuously, with maximal efficiency of nutrients uptake. Controlled release fertilizers save labor and application costs. Their application is independent of the irrigation system, and does not require sophisticated equipment.

Taking advantage of MulticoTech™ polymer coating technology, Haifa produces Multicote® line of controlled release fertilizers.

Multicote® Products

Multicote® for nurseries and ornamentals; NPK formulae with release longevities of 4, 6, 8, 12 and 16 months
Multicote® Agri / Multigro® for agriculture and horticulture
CoteN™ controlled-release urea for arable crops
Multicote® Turf / Multigreen® for golf courses, sports fields, municipals and domestic lawns

Appendix II: Conversion tables

From	To	Multiply by	From	To	Multiply by
P	P_2O_5	2.29	P_2O_5	P	0.44
P	PO_4	3.06	PO_4	P	0.32
H_3PO_4	H_2PO_4	0.9898	H_2PO_4	H_3PO_4	1.38
K	K_2O	1.20	K_2O	K	0.83
Ca	CaO	1.40	CaO	Ca	0.71
Mg	MgO	1.66	MgO	Mg	0.60
S	SO_3	2.50	SO_3	S	0.40
S	SO_4	3.00	SO_4	S	0.33
N	NH_4	1.28	NH_4	N	0.82
N	NO_3	4.43	NO_3	N	0.22

From	To	Multiply by	From	To	Multiply by
Acre	Hectare	0.405	Hectare	Acre	2.471
Kilogram	Lbs	2.205	Lbs	Kilogram	0.453
Gram	Ounces	0.035	Ounces	Gram	28.35
Short Ton	MT	0.907	MT	Short Ton	1.1
Gallon (US)	Liters	3.785	Liters	Gallon (US)	0.26
Kg/Ha	Lbs/acre	0.892	Lbs/acre	Kg/Ha	1.12
MT/Ha	Lbs/acre	892	Lbs/acre	MT/Ha	0.001

1 meq	Correspondent element (mg)	1 mmol	Correspondent element (mg)	Weight of ion
NH_4^+	14 mg N	NH_4^+	14 mg N	18 mg NH_4^+
NO_3^-	14 mg N	NO_3^-	14 mg N	62 mg NO_3^-
$H_2PO_4^-$	31 mg P	$H_2PO_4^-$	31 mg P	71 mg P_2O_5
HPO_4^{2-}	31 mg P	HPO_4^{2-}	31 mg P	35,5 mg P_2O_5
HPO_4^{2-}	15.5 mg P	K^+	39 mg K	47 mg K_2O
K^+	39 mg K	Ca^{2+}	40 mg Ca	28 mg CaO
Ca^{2+}	20 mg Ca	Mg^{2+}	24 mg Mg	20 mg MgO
Mg^{2+}	12 mg Mg	SO_4^{2-}	32 mg S	48 mg SO_4
SO_4^{2-}	16 mg S	Na^+	23 mg Na	-
Na^+	23 mg Na	Cl^-	35.5 mg Cl	-