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A. Introduction, Citrus plantations feature a very important tree crop

Citrus is one of the most popular and widely grown fruit crops in the world. Global citrus production amounted to 162 million MT (metric tons) in the 2021/22 crop season, being the second most produced fruit worldwide in 2021, and cultivated in more than 10.2 million hectares. World citrus production and exports have grown steadily over the past three decades. Citrus fruits are consumed mainly at their fresh form, but about one-third of the worldwide production is used for processing. All citrus fruits are a rich source of vitamins, minerals and dietary fiber, essential for human nutritional well-being. Oranges account for more than half of world's citrus production, and are the most widely traded citrus fruit, followed by tangerines, lemons and grapefruits. Citrus crops are grown in nearly all countries located between 40° north and south latitudes, where minimum temperatures are generally greater than -7°C.

B. Citrus soil requirements

Citrus trees grow best on sandy-, and loamy soils, because, they have a shallow root system, and because their nutrient absorption capacity is rather low, due to relatively small number of root hairs. Therefore, well aerated, fertile soils are preferred. High organic matter is favorable. Most trees' rootlets, which absorb water, minerals and air, are found in the upper 60–80 cm of the soil, especially at 0–30 cm upper soil layer, up to 2 meters horizontal distance from the trunk. But orchards growing in tropical regions require exceptionally high drainage for the upper >150 cm of soil. Planting on 30–50 cm high ridges can ameliorate poorly-aerated soils. High-drainage requirement is necessary also due to a serious soil-borne root-rot disease, provoked by the fungus '*Phytophthora citrophthora*' that thrives in waterlogged soils.

Citrus grow well at soil pH range of 4–9, but ideal pH for light-textured soils ranges 5.5–6, which enables optimal nutrients availability. Increasing pH value, in acidic soils is practiced by application of N fertilizers as nitrate, by soil application of gypsum, ground limestone and/or dolomite. Reducing alkaline soils' pH is achieved by applying ammoniacal N fertilizers, because when the plants take them up, their roots excrete H^+ cations to the soil, thus acidifying it. Applying urea as a nitrogen source works in a similar way, because it is converted to ammonium shortly (1-2 days) after application.

C. Fertilization of young citrus trees

Table 1: Fertilization recommendations by fertigation for young citrus trees, planted at 300-400/ha

Plant age in field (years)	**Plant requirement** (g/plant/season) *			**Products application** (kg/plant/season) *
	N	P_2O_5	K_2O	GATIT 21-7-21
1	100	35	100	0.475
2	160	50	160	0.760
3	240	80	240	1.140
4	360	120	360	1.715
5	480	160	480	2.285

*: Total application during the entire irrigation season

D. Fertilization of fruit-bearing citrus trees

Besides irrigation, mineral nutrition is the most important factor influencing fruit yield and quality. The actual nutrition scheme must take into consideration: the variety/rootstock, tree age, trees density, expected yield, soil type, availability of soil nutrients, seasonal conditions, desired final fruit size and expected harvest time. Knowing the amounts of mineral elements, removed with the fruits from the orchard's soil, can be used to closely estimate the amounts and timing of fertilizers application, in order to obtain optimal nutrients' use efficiency. These values are detailed in tables 2 &3. Of course, specific efficiency constants must be considered, when calculating the total application rates of the various nutrients. Under the advanced system of drip fertigation, these constants are: 0.95 for N, 0.45 for P, and 0.80 for K.

Table 2: Macro-, and secondary nutrients removed from the soil by the fruit

Crop	N	P_2O_5	K_2O	CaO	MgO
	g/MT of fresh fruit				
Orange	1850	390	2150	1090	282
Tangerine	4450	450	3230	706	300
Lemon & lime	1638	366	2086	658	209
Grapefruit	1058	298	2422	573	183

Table 3: Micro-nutrients removed from the soil by the fruit

Crop	Fe	Mn	Zn	Cu	B
	g/MT of fresh fruit				
Orange	3.0	0.8	1.4	0.6	2.8
Tangerine	2.6	0.4	0.8	0.6	1.3
Lemon & lime	2.1	0.4	0.7	0.3	0.5
Grapefruit	3.0	0.4	0.7	0.5	1.6

Dynamics of nutrients uptake, throughout the fruits' developmental stages

Knowing the total removal amounts of the nutrients, is helpful for deciding on the entire application rates of the various nutrients. Then, it is very important to know the nutrients' requirement rates, as related to their phenological stages, because this helps applying the appropriate rates at their most optimal growth stages. Figure 1 is instrumental in this context.

Figure 1: Nutrients uptake dynamics as related to the phenological stages of orange trees' fruits

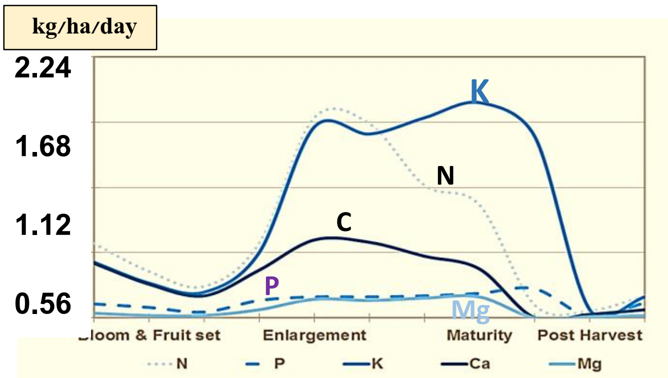

Table 4. Nutritional requirements of fruit-bearing orange trees, by trees' phenological stage

Nutrient	g/MT of mature fruits	Bloom & fruit-set	Fruit growth	Fruit bulking up to harvest	Post-harvest
		% per stage			
N	1850	16	48	32	14
P_2O_5	390	22	33	34	11
K_2O	2150	10	40	45	5
SO_3	336	16	48	45	14
CaO	1090	26	40	25	9
MgO	282	15	28	43	14

However, it is most advisable to apply the fertilizers continuously by fertigation, at variable rates throughout the entire irrigation period.

Gat -Fertilizers agronomists' recommendation

Macro-nutrients rates by expected yields and area conditions*.

This recommendation relates to citrus grove grown on moderately alkaline soils (> pH 7) , with climate condition featuring 7 months of dry season (fertigation period), and 5 rainy months.

FERTILIZATION PROGRAM FOR

Crop	CITRUS
Scenario	Season-long fertilization
Total Macro nutrients	N - P_2O_5 - K_2O
Kg/hectare	215 - 146 - 228
Expected yield	60-70 Metric ton / ha
Trees density	300-400 trees/hectare

STAGE	FERTILIZER	N	P_2O_5	K_2O	Kg/ha per week	Number of weeks	Total kg/ha per stage
During 2 months as of early flowering	GATIT	14	28	18	40	8	320
During following 4 months	GATIT	21	7	21	45	18	810

*	**These recommendations are general guidelines only. Please consult Gat Fertilizers' agronomists for optimizing these instructions to your local conditions.**

	Instructions for preparation of 500 liters of stock solution*
(1)	Clean a 500-liter tank for storing the stock solution.
(2)	Fill half of it with clean water (250 liters).
(3)	Dissolve 125 kg (5 bags of GATIT, 25 Kg each) in the tank. STIR WELL!
(4)	Fill up to the 500-liter water mark, with clean water.
(5)	STIR WELL to obtain complete dissolution of the fertilizer.
(6)	Inject the stock solution into de irrigation system by dosing it throughout the irrigation session.
(7)	This amount of stock solution takes care of 3.125 ha, for one week

E. Nutrition control by leaf analysis

Leaf analysis is a very useful and reliable tool to diagnose the nutritional status of a citrus plantation. Table 5 indicates the nutrients' concentration values according to their deficiency/sufficiency categories. These leaf analyses are generally performed from mid-August to early October (northern hemisphere), sampling healthy leaves belonging to 4-6-months-old spring-flush of nonfruiting branches. Leaf analysis is a helpful guide in citrus orchard nutrition, and it is a better indicator than soil testing, for most nutrients, but it can never replace human observation and experience.

Table 5: Leaf analysis standards for most citrus crops, on dry mass basis, (ref. California).

Nutrient	Deficient	Low	Optimal	High	Excessive
N (%)	<2.2	2.2 – 2.4	2.5 – 2.6	2.7 – 3.0	>2.8
P (%)	<0.09	0.09 – 0.11	0.12 – 0.16	0.17 – 0.29	>0.30
K (%)	<0.40	0.50 – 0.69	0.70 – 1.09	1.10 – 2.30	>2.30
Ca (%)	<1.5	1.6 – 2.0	2.10 – 3.00	3.0 – 5.0	>5.0
Mg (%)	<0.2	0.2 – 0.27	0.28 – 0.40	0.41 – 0.7	>0.8
S (%)	<0.05	0.1 – 0.2	0.2 – 0.5	0.6 – 1.0	> 1.0
Fe (ppm)	<35	36 - 147	148 – 180	180 – 200	>200
Zn (ppm)	<16	17 – 24	25 – 100	101 – 300	>300
Mn (ppm)	<16	17 – 24	25 – 200	200 – 1000	>1000
B (ppm)	<21	22 – 30	31 - 100	100 – 260	>260
Cu (ppm)	<3	3 – 9	10 – 17	18 – 20	>20
Mo (ppm)	<0.05	0.06 – 0.09	0.1 – 1.0	2.0 – 5.0	>5.0
Cl (ppm)			500 –1000	1100 –2000	>2000