Citrus *(Citrus spp., etc.)*

French: Agrumes; Spanish: Citricos; Italian: Agrumi; German: Zitrusfruechte

Citrus fruits belong to six genera (Fortunella, Eremocitrus, Clymendia, Poncirus, Microcitrus and Citrus) native to the tropical and subtropical regions of Asia and the Malay Archipelago, but the major commercial fruits are species of Citrus. The principal scions and rootstocks are:

Scions:	**Rootstocks:**
Orange (C. sinensis Osbeck)	Rangpur lime (C. limonia Osbeck)
Mandarin (C. reticulata Blanco)	Rough lemon (C. jambhiri Lush.)
Lemon (C. limon [L.] Burm.)	Sour orange (C. aurantium L.)
Lime (C. aurantifolia [Christ.] Swing.	Cleopatra mandarin (C.reshni Hort.)
Grapefruit (C. paradisi Macf.)	Trifoliata (P. trifoliata [L.] Raf.)
Pomelo (C. grandis [L.] Osbeck)	

Crop data

Perennial, grown in a wide range of soil types and climatic conditions.

Soil: sand to loam to clay, acid to alkaline.

Climate: arid to humid where minimum temperature permits.

Plant density: 175-500 trees/ha, with newer and younger plantings having the higher density.

Useful life: 15-40 years depending on soil type. In general, trees on well drained sandy soils have a longer useful life than those on loam or clays where drainage is not as good.

Producing age:

- for intensive culture (with fertilizer use, and close monitoring and control of insect pests, diseases and weeds, and of irrigation and tree size): beginning second year, peak 10-30 years, yield 30-60 t/ha.

- for extensive culture (with fertilizer use, but only moderate monitoring and control of insect pests, diseases and weeds, and mostly unirrigated): beginning fourth year, peak 8-15 years, yield 15-25 t/ha.

The crop is grown in a belt between 40 °N and 40 °S, except at high elevation. Minimum temperature is the limiting factor, though the killing effect varies with variety, rootstock, dormancy of the trees, the absolute minimum temperature and its duration.

24 countries account for about 85 % of production. Brazil is the largest producer of oranges, and Japan of mandarins. Spain, Italy and Mexico lead in the production of lemon and limes, while USA produces the most grapefruit.

World production is expected to increase during the 1990s as new plantings in North and South America, the Mediterranean region and Asia come into full production. It is expected that the

volume of processed fruit will continue to increase while consumption of fresh fruit should remain relatively constant.

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.

Nutrient removal - Macronutrients						
Variety	**grams per ton of fresh fruit**					
	N	**P2O5**	**K2O**	**MgO**	**CaO**	**S**
Orange	1 773	506	3 194	367	1 009	142
Mandarin	1 532	376	2 465	184	706	111
Lemon and lime	1 638	366	2 086	209	658	74
Grapefruit	1 058	298	2 422	183	573	90
Sources: Koo, 1958; Chapman, 1968; Malovolta, 1989.						

Nutrient removal - Micronutrients					
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
Sources: Koo, 1958; Chapman, 1968; Malovolta, 1989					

Soil analysis

This is useful for measuring pH, available P and certain exchangeable cations, notably Ca and Mg. However, because citrus trees are planted 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.

Plant analysis data

Sufficient progress has been made to use leaf analysis as one of the guides in planning citrus fertilizer programmes. 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.

Plant analysis data - Macronutrients **4 - 6 months old spring cycle leaves from nonfruiting terminals**	
Range	**% of dry matter**

	N	P	K	Mg	Ca	S
Deficient	<2.20	<0.09	<0.70	<0.20	<1.50	<0.14
Low	2.20-2.40	0.09-0.11	0.70-1.10	0.20-0.29	1.50-2.90	0.14-0.19
Optimum	2.50-2.70	0.12-0.16	1.20-1.70	0.30-0.49	3.00-4.90	0.20-0.39
High	2.80-3.00	0.17-0.29	1.80-2.30	0.50-0.70	5.00-7.00	0.40-0.60
Excess	>3.00	>0.30	>2.40	>0.80	>7.00	>0.60
Sources: Smith, 1966; Koo, 1984; Malavolta, 1989.						

Plant analysis data - Micronutrients 4 - 6 months old spring cycle leaves from nonfruiting terminals						
Range	ppm dry matter					
	Fe	Mn	Zn	Cu	B	Mo
Deficient	<35	<17	<17	<3	<20	<0.05
Low	36-59	18-24	18-24	3-4	21-35	0.06-0.09
Optimum	60-120	25-100	25-100	5-16	36-100	0.10-1.0
High	121-200	101-300	101-300	17-20	101-200	2.0-5.0
Excess	>200	>500	>500	>20	>250	>5.0
Sources: Smith, 1966; Koo, 1984; Malavolta, 1989.						

Perhaps the most distinctive feature of citrus nutrition is the large number of nutrient deficiencies that have been encountered in intensive cultivation. Foliar symptoms of deficiencies of N, P, K, Mg, Ca, Mn, Zn, Cu, Fe, B and Mo have been recognized in the field as well as in artificial culture. In order to obtain maximum yield of high quality fruit, it is essential to evaluate the crop's nutritional requirements locally and to provide a balanced fertilizer programme.

Fertilizer recommendations

Pre-plant

Available organic manures should be applied and well incorporated into the soil before planting. This practice is widely adopted in many developing countries. Typically, a planting hole about 1 metre in diameter and 1 metre deep is dug; compost, animal manure and green manure are mixed with the soil that has been dug out, and the mixture is then replaced in the hole before the tree is planted. Tree planting holes are not used in developed countries, because of scarcity of organic maure. On acid soils, limestone is usually added to the mixture for pH adjustment or, where organic manure is scarce, soil preparation consists simply of liming. On some alkaline soils in arid regions, pre-plant irrigation is often used to leach excess salts from the surface soil.

Young trees

N, P and K are the principal components of the recommended fertilizer treatment. The quantities applied vary with soils, fertility, local conditions and intensity of cultivation. Differences are illustrated in the table which shows recommendations from four citrus-producing countries in S. America, N. America, Africa and Asia respectively.

Fertilizer programmes for young trees							
Country	Tree age in years	grams per tree					
		N	P2O5	K2O	MgO	Bone* meal	Wood** ash
Brazil	1	100	0	20			

	2	160	160	80			
	3	240	240	160			
	4	360	320	320			
	5	480	400	400			
	6	600	480	480			
USA, Florida	1	200	200	200	65		
	2	330	330	330	110		
	3	440	440	440	150		
	4	500	500	500	165		
	5	580	580	580	190		
	6	640	640	640	220		
Côte d'Ivoire	1	65	0	20	200		
	2	85	0	30	400		
	3	115	55	120	400		
	4	280	80	170	600		
	5	380	110	230	800		
	6	540	160	350	600		
India	1	50	100			500	1 500
	2	100	200			1 000	3 000
	3	150	300			1 500	4 500
	4	200	400			2 000	6 000
	5	250	500			2 500	7 500
	6	300	600			3 000	9 000
* Bone meal: 3.0 % N; 25 % P_2O_5; 0.2 % K_2O; 20 % Ca. ** Wood ash: 0.0 % N; 1.8 % P_2O_5; 5.5 % K_2O; 2.2 % Mg; 23 % Ca.							

As can be seen from the table, the quantity of fertilizer applied increases with the age of the tree.

The area to which the fertilizer is applied also increases with the age of the tree. Generally where tree-planting holes are used, fertilizer is applied to the surface area of the hole because not many roots will grow beyond it. Where tree-planting holes are not used, the tree canopy serves as a guide; fertilizer is applied from about 30 cm beyond the drip line of the tree canopy inwards towards the centre of the tree.

The frequency of application of fertilizer decreases with the age of the tree, ranging from 5-7 applications in the first year to 3-4 applictions in the fifth year; but, where "fertigation" is practised, trees usually receive fertilizer 25-30 times a year during the first 5 years.

Country notes

Brazil
The crop is planted on loam soils which are relatively infertile but have enough organic matter to give a cation exchange capacity of about 7. Young trees appear healthy and well fertilized. Most plantings are unirrigated. Trees begin producing in the third year.

Florida, USA
The crop is grown on sandy soil with very low fertility and organic matter, and a cation exchange capacity of 2-3. Despite being in the humid region with adequate rainfall, irrigation is practised because of the sandy soils' low water-holding capacity. Growers follow an intensive programme;

large amounts of fertilizer are applied, mostly through "fertigation", and the young trees respond well; it is not uncommon for them to produce 20 kg of fruit in the second year.

Côte d'Ivoire
Cultivation is similar to that of many developing countries where much of the organic manure and mineral fertilizer used is incorporated in the planting hole. Only small quantities of mineral NPK fertilizer are applied during the first 3 years but appliction increases thereafter when the trees begin to produce fruit. Mg is a regular component of the young tree fertilizer in both Florida and the Ivory Coast but not in other regions.

India
Here, and in other Asian citrus-producing countries, K is not a regular component of the young tree fertilizer but comes from organic sources. It is questionable, however, whether the K requirement of citrus can be met from organic sources alone; symptoms of inadequate K are frequently observed in both India and China.

Mature trees

Fruit production and quality are the principal considerations. The macronutrients influence fruit quality both externally and internally. Nutrient removal in the expected yield, leaf analysis and soil analysis can all be of value in planning the fertilizer programme for mature trees.

N and K are the key elements; P is less critical because of the much smaller amount removed in the harvested fruit. Fertilizer for mature trees usually contains NPK in the proportions N:P2O5:K2O = about 1.0:0.2:1.0. Mg is included where it is needed. Around 3-6 kg N are required to produce one ton of fruit. N is often used as the basis from which to calculate the estimated requirements of other nutrients.

Examples of recommendations for mature trees

Country	kg/ha			
	N	P2O5	K2O	MgO
Japan	150-350	115-205	115-235	-
Brazil	150-240	40- 80	90-320	-
Florida, USA	180-320	30- 60	180-360	75-210

Fertilizer for mature trees is usually given in two applications (fall-winter and spring) or in three applications (spring, summer, fall) yearly.

Micronutrients

In general, these do not affect fruit production or quality unless they are in severe deficiency, for which leaf analysis and visual observations are the best guides. Any deficiencies, or excess, should be corrected for the health of the tree.

Guidelines for the use of micronutrients, based on Florida experience, are summarized below. Some adjustment may be needed for other parts of the world, though it should be borne in mind that in Florida attention to micronutrients is a regular part of the citrus fertilizer programme and much research has entered into the development of these guidelines.

Guidelines for micronutrient application methods, timing and rate

Method and Rates	Mn	Zn	Cu	Fe	B	Mo
Foliar application (when trees have the most fully expanded new leaves)	Yes	Yes	Yes	No	Yes	Yes
Rate in grammes/litre	0.9	1.2	0.9	-	0.06	*
Soil application (any time)	Yes°	No	Yes	Yes	Yes	No
Rate in kg/ha	10.0	-	5.4	#	1.0	-
° Not recommended for alkaline soil. * 34-36 g sodium molybdate per litre # On acid soil, FeEDTA at 20 g Fe/tree; on alkaline soil, FeEDTAOH at 50 g Fe/tree						

Further reading

EMBLETON, T.W.H.; REITZ, H.J.; JONES, W.W.: Citrus Fertilization. In: REUTHER, W. (ed.): The Citrus Industry, vol. III. University of California, Div. Agric. Sciences, Berkeley, CA, USA (1973)

KOO, R.C.J. et al.: Recommended Fertilizers and Nutritional Sprays for Citrus. Florida Agriculture Experiment Station Bul. 536D, USA (1984)

KOO, R.C.J.: Citrus. In: PLUCKNETT, D.L.; SPRAGUE, H.B.(eds.): Detecting mineral nutrient deficiencies in tropical and temperate crops. Westview Tropical Agriculture Series N° 7 (1989)

MALAVOLTA, E.; NETTO, A.V.: Nutricao mineral, calagem, cessagem e adubacao dos citros. Associacao Brasileira para Pesquisa da Potassa e do Fosfato, Piracicaba - SP, Brazil (1989)

RAJPUT, C.B.S.; HARIBABU, R.S.: Citriculture. Kalyani Publishers, New Delhi - Ludhiana, India (1985)

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