1 INTRODUCTION

The most important environmental factors that influence photosynthesis, flowering, fruit set, fruit growth and fruit quality are light, water and nutrition. Inorganic nutrition of plants was raised for the first time during 1840 when Justus von Liebig published his book on this subject. Since then 17 elements have been identified as essential for plant production. Fourteen of these elements, i.e. Nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sulphur (S), chloride (Cl), iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), boron (B) and molybdenum (Mo), are utilised and taken up from the soil and water. The other three, carbon (C), hydrogen (H) and oxygen (O) are utilised and taken up from the air and water.

The mineral component of plant material is small and variable and depends on the plant part, age and conditions in which they were produced. The mineral component of citrus is highest at 17% of the total mass of plant material (Table 1).

Table 1. Average mass of ash in citrus tissue

Plant part	Ash content* (%)
Fruit	0.4 – 1.0
Leaves	6 – 17
Shoots	4 – 6
Wood	2 – 7
Roots	2 – 4

*The ash content is the residue after all moisture and organic material is burned away. It contains all the nutritional elements except carbon, hydrogen, oxygen and nitrogen, and usually not sulphur and chloride.

Through the years, in the endeavours to increase plant production, a number of approaches have been tested for inorganic nutrition.

- Right at the beginning the main objective was to determine, which elements were necessary for plant production.
- The next step was to identify deficiency symptoms.

Next it was endeavoured to improve production by manipulating the inorganic nutrition. The first attempt was based on the amount of minerals that are removed by the crop from the orchard (Table 2). The reasoning was that at least the same amount must be replaced.

Table 2. The average mass of some nutrients removed by the crop.

Element	Gram per ton of fruit	Adapted values in grams per ton fruit to compensate for fertiliser efficiencies.
Nitrogen as N	1900-2250 for lemons 1900-2250 for satsumas 2000-2250 for grapefruit 2000-2250 for navels 2000-2250 for the rest	2750-3000 for lemons 2000-2500 for satsumas 2000-2500 for grapefruit 2500-2750 for navels 2250 tot 2500 for the rest
Phosphorus as P	450-500 for satsumas 450-500 for the rest	500-650 for satsumas 400-500 for the rest
Potassium as K	2000-2250 for old clone Valencias 2000-2250 for the rest	2750-3000 for old clone Valencias 2250-2500 for the rest
Calcium as Ca	500-600	500-600
Magnesium as Mg	500-600	500-600
Sulphur as S	300-500	300-500

The values in the third column can be applied to determine the efficiency of the fertilisation program, especially that of nitrogen. An additional factor was incorporated to provide for manipulations that can be done on certain cultivars, e.g. with lemons the number of fruit can be increased to get smaller fruit according to the demands from the market.

- The main result of the use of removal figures was that plant analysis became important. Leaf analysis has come to the front and has received the most attention. The figures in Table 2 can be further refined by also taking the expected effectiveness of the fertilisers into consideration. The probability that 100% of any nitrogen source will be absorbed by the trees is zero. The efficiency of nitrogen sources is usually taken as 80%, phosphorus as 30 – 40% and potassium as 50%. Thus, when a crop removes 200kg N, 200x100÷80=250kg N must be replaced.
- A logical result of leaf analysis was the developing of threshold values. According to this theory, production would increase if the mineral supply or the concentration of the nutritional elements increase till it reaches a level whereafter the increase in production ceases (Figure 1). Shortly thereafter leaf analysis was recognised as a diagnostic method.

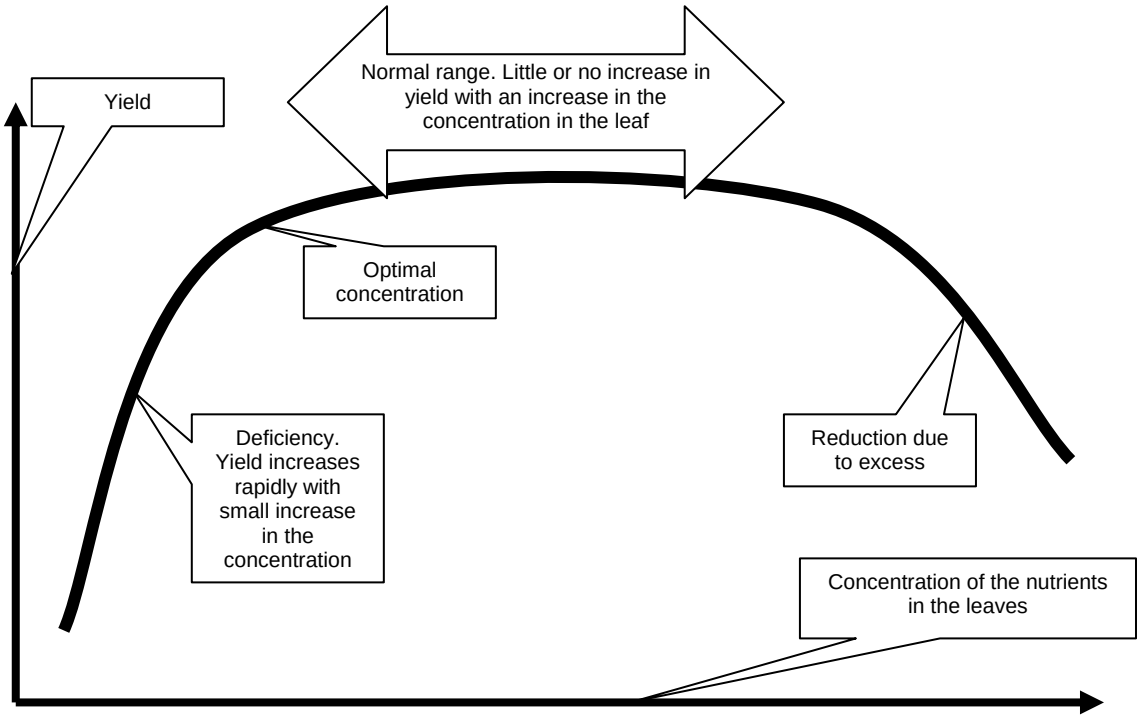

Figure 1. The relationship between the concentration of the nutrients in the leaves and yield.

- The next step was to concentrate on certain plant parts and physiological processes. Fruit, vegetative growth, fruit set, cell division and cell growth and their relationship with mineral nutrients were investigated. Well known applications of this work are the timing of nitrogen and foliar sprays with potassium nitrate, zinc and boron.

- Nowadays we strive to manipulate physiological processes in order to increase the utilization of mineral nutrients. One example is the re-mobilisation of precipitated calcium oxalate to increase the calcium of the apple fruit.

No matter which method is used, plant analysis especially leaf analysis will form an integral part. Today it is necessary to evaluate the role of each nutrient element in production and to use the most effective method for effective supply. The most sustainable income will be generated when nutrients are supplied in the most economical way, which ultimately is the goal of a good fertilisation program.

In the following subsections, the role of each of the 14 elements will be discussed. Thereafter the practical application of this information on citrus production will be discussed. During the discussions distinctions between fertilising by conventional applications on the soil and fertigation will be highlighted. Fertigation is further divided into applications through microjets and drippers because different approaches are required. The differences are mostly related to the volume of the soil fertilised. With drippers the volumes of soil varies between 100 and 500 litre and with microjets between 2000 and 5000 (and even more) litres. An application of 10g N with drippers is effective because it represents a concentration of 20 and 100mg N per litre of soil. The same application is not effective with microjets because the concentration is then only 2 to 5mg N per litre of soil.

In the list of sources those products that I am familiar with, are included. These sources are not necessarily recommended but are included (in anyway). Trials with new sources should be done by treating only a few rows or half of the orchard. Take leaf samples from the two treatments to establish the value of the "new" product. Also look out for any

visible symptoms on the trees, yield, fruit size, etc.
This publication is in no way complete and is never intending to be. The idea is to concentrate on the principals, which can be applied in practice and results and observations which can benefit production and quality. Aspects of nutrition and fertilising of citrus, which are discussed elsewhere and are readily available will not be repeated here. That includes aspects of physiology, leaf symptoms and standard practises. For more information regarding these, the following publications can be used.

Marschner, Horst. 1988. Mineral nutrition of higher plants. Academic Press. ISBN 0-12-473542-8 (HB) ISBN 0-12-473543-6 (PB).

Burt, C., O'Conner, K. & Ruehr, T. 1998. Fertigation. Irrigation Training and Research Centre. California Polytechnic State Univ. San Luis Obispo CA 93407. ISBN 0-9643634-1-0.

Reuther, W., Batchelor, L. D. & Webber, H. J. 1968. Editors of The Citrus Industry. Volume 2.

Reuther, W. 1973. Editor of The Citrus Industry. Volume 3.