28 FERTILISATION OF BEARING TREES

The most important requirement of a good fertilisation program is that it must only supply those elements that the trees cannot obtain in sufficient quantities from the soil and water to maintain optimal levels for all 14 nutrient elements. The other aim is to supply the required fertilisers at the lowest cost to render the highest income. That does not implicate that the cheapest fertiliser must be applied. A balanced fertiliser mix does not exist, except perhaps with fertigation and drippers where the water and soil contribute nothing to the nutrient program. But even with single line drippers, the composition of the water needs to be considered and can supply the complete requirement for calcium, magnesium and sulphur. The possibility that a mix like 3:1:5 will satisfy the requirements of all orchards on a farm is very slim. A balanced nutritional status is the results of the ability of the roots to absorb the required nutrients, in the required quantities/ratio. Experience confirmed that trees in the same orchard may have a different nutritional status.

The concept of a "balanced" fertilisation program or nutritional status is used often out of context and is sometimes misused to press a certain sales point. Guano was at a stage regarded as being a "balanced" fertiliser although the sea birds have no knowledge of citrus and they only want to get rid of the guano. A certain fertiliser may be balanced for a specific condition, but can be totally off target for the 90% of other applications. The only balanced fertilisation program is the one that is prepared for a specific orchard. Others are based on averages and usually applies too much (usually phosphorus) of one or more of the nutrients.

The following information is required to formulate an effective fertilisation program.

- The current nutritional status (leaf analyses).
- The historical nutritional status, especially that of the previous season (data base).
- Current composition of the soil.
- Current composition of the irrigation water.
- Historical composition of the soil and water.
- Information on the crop for the last two seasons.
- Estimates on the current crop.
- Fertilisers and foliar sprays applied.
- Practises to improve fruit set, fruit thinning, fruit size etc.

These information needs to be evaluated together with all the other information discussed in the previous chapters to formulate a fertilisation program for the coming season.

Nutritional status

The nutritional status is measured by leaf analyses. Leaf analyses summarise the ability of the trees to set an optimal crop and grow it to maturity. The nutritional status is measured before fruit set and will remain stable until the first nitrogen is applied. The current nutritional status is the accumulated effects of all the inputs including the previous fertilisation program. The success of all the inputs is measured by means of the yield, fruit size and fruit quality. If the accumulated inputs result in an optimal crop the fertilisation program must be repeated. If any looming imbalance is detected it need to be corrected during the coming season.

Unfortunately many other factors than fertilisation will affect yields and quality. It is therefore possible to maintain an optimal nutritional status but still not produce an optimal crop. In such a case the impact of any possible nutrient deficiency, excess or imbalance must be ruled out, before other factors are considered. Sometimes it is possible to counteract the effect of another factor, by adjusting the fertilisation program. A well know example is creasing. Although the incidence of creasing is primarily due to climatic conditions, the expression of creasing can be hidden by promoting thicker skins through higher N and K and a lower P levels.

The following steps indicates the processes that needs to be followed when evaluation the nutritional status of the trees.

- Compare the results of leaf analyses with the set of norms.

This is a simple process to indicate which elements are not present in optimal concentrations.

- Compare the results with the previous ones, if available.

This will indicate whether the fertilisation program applied resulted in any changes and to indicate trends. For instance, if the current concentration of P is 0,12%, it means an optimal status However, compared to that of the previous season (0,14) it means a decrease and one can expect the next analyses will indicate a too low status unless some P is applied. If the results of two seasons ago are available, a much clearer picture will be available. When microjets are used for irrigation, P is not applied every year. Therefore it is important to follow the trend of concentration of P rather than the actual concentration. When drip irrigation is used, P has to be supplied continuously and the trend in the example will be used to change the concentration in the nutrient solution.

The type of irrigation used in the above example is irrelevant. The analytical results indicate that the P supply was too low. Whether it is supplied through the irrigation water or from the reserves in the soil, the rate must be increased. How this is done depends on the irrigation system. With microjets supers needs to be banded and with drippers the concentration in the nutrient solution must be increased.

The same argument applies to all other nutrient elements. When the supply is too low, it has to be increased. The supply can also be increased by improving the efficiency of the fertilisers. For instance when the supply of nitrogen is too low, the efficiency can perhaps being improved by split applications that will supply N to the plants over a longer period. The supply of N will then be improved without increasing the mass of N.

Other methods to increase the supply of nutrients are foliar sprays. The zinc status of the trees can effectively being improved by a foliar spray which is preferred to soil applications. Even with foliar sprays can the efficiency of the spray being improved by acidification.

From the above it is clear that more than a set of leaf analyses data is required to formulate an effective fertilisation program.

- Evaluating the previous fertilisation program.

Gathering information on previous applications is not to spy on anyone but to add to the value of leaf analyses and to improve on the previous program.

The basic information required is W_2H_2. What, When, How much and How was the fertiliser applied.

What is applied?
All fertilisers are not equally effective under all conditions. By changing the source of a nutrient, the supply of that nutrient can be improved. Examples of such possibilities are listed in Table 75.

Table 75. List some benefits arising from changing the source of the nutrient elements.

Source and condition	Alternative source or method of application	Benefits
Urea on sandy and cold soils.	Ammonium nitrate in AN19 or LAN	The hydrolyses of urea is slow in cold and sandy soils. Unhydrolysed urea will leach very easily. Use urea when the soil temperature >15°
Urea spread out on alkaline soils.	Ammonium nitrate in AN19 or LAN of ammonium sulphate	Volatilisation can be reduced and with ammonium sulphate acidification is higher which will increase the availability of iron.
Ammonium nitrate in AN19 or LAN and urea	Ammonium sulphate	When sulphur is also required.
Ammonium nitrate in AN19 or urea with drippers and high concentrations of Cl	Potassium or calcium nitrate	The application of nitrates, especially calcium nitrate suppress the effect of Cl
Soil applications of N when root rot is a problem.	Foliar sprays with urea or potassium nitrate.	Bypass the root system and increase the supply. The mass that can be applied by foliar sprays is limited.
MAP broad cast	Super phosphate banded	Reduce fixation of P
Phosphoric acid through drippers	MAP	The combination of NH_4^+ and $H_2PO_4^-$ stimulate root development
Phosphates and acid soils	Lime	By increasing the pH more P will be mobilised and could satisfy the demand.
Phosphates through drippers in an acid soil g	NO_3:NH_4	Change the ratio to 80:20 or even 100:0 until the pH is neutral. More P gets mobilised at a neutral pH.
Potassium chloride and drippers	Potassium nitrate	The combination of K and NO_3 is more effective
Potassium chloride and alkaline soils	Apply potassium chloride at low rates over a prolonged period. (Low dosage high frequency.)	Without changing the source or mass, potassium will be utilised better.

- **Evaluating crop data**

Crop data includes yield, fruit size and several quality parameters. By evaluating more than one year's data, information is gathered aiding in formulating a more purposeful fertilisation program. Examples include alternate bearing, when the incidence of too small fruit and creasing increase during the "on year" too coarse fruit from young trees or trees carrying a small crop, too green fruit etc. The more information supplied, the better the fertilisation program.

- **Condition of the trees**

The hidden deficiency symptoms of nitrogen and magnesium (see chapters 2 and 5) can reduce the value of leaf analyses and even worse create erroneous deductions. Therefore is it necessary to have information about the foliar coverage of the trees. Deficiencies of calcium and iron cannot be detected by leaf analyses and additional information is required.

A hidden nitrogen deficiency indicates a lower nitrogen status as what the leaf analyses show and this will have an impact on yield and even fruit size. This can only be identified by a visual inspection of the trees.

Information on climate and skin qualities is required to shed more light on possible calcium deficiencies.

Like nitrogen the hidden magnesium deficiency will only be detected by visual inspection. Too small fruit notwithstanding an optimal potassium status might be due to a too low magnesium status.

Only under very rare conditions will an iron deficiency be identified by leaf analyses. Visual inspection is required. An iron deficiency can result in losses in yield and quality although the leaf analyses indicate an optimal nutritional status.

Application of fertilisers

As far as application of fertilisers is concerned, the mass, timing and method are the most important aspects.

- Mass.

The aim of a good fertilisation program is to optimise the nutritional status of the trees at the lowest input cost. The mass is determined on the basis of applying a certain mass of fertilisers, then evaluate the result after about 8 to 9 months (leaf and crop analyses) and the adjust the previous program.

For instance if 1000g LAN was applied at the right time and the leaf analyses indicates a low nitrogen status and the yield was acceptable but can be better, the conclusion will be to increase the LAN application. But if the information on the mass of LAN applied was incorrect and only 650g was applied then the conclusion is to increase the 650g.

It is also important to realise that two adjacent and identical orchards can have different nutritional status although they were treated exactly the same. For this reason a leaf sample should not represent too many trees. The ideal is a maximum of 1000 trees per sample.

Another method to determine the mass of fertilisers to apply is to calculate the mass removed by the crop (Table 2). For instance if 150kg navel fruit is produced per tree the mass of nitrogen removed will be 150x2500/1000 = 375g nitrogen which is equal to the application required. This is only a starting point and must be refined based on analyses of the nutritional status and crop information.

Adjustments can also be based on the leaf analyses. If the leaf analyses indicate a high status, then the 375g can be reduced.

The same removal figures can be used to evaluate the efficiency of the nitrogen application. For example if a crop of 150kg per tree was produced with an application of 500g N per tree the efficiency rate is 150x2500÷1000 = 375÷500x100 = 75%. This means that 25% of the applied N is not reflected in the yield. With young trees this is acceptable due to nitrogen required for vegetative growth. In mature trees an efficiency rate of 80 to 100% is acceptable. If the efficiency rate is more than 100%, the trees receive N from another source. This then needs to be investigated.

The efficiency of a phosphorus application can only be evaluated by the maintenance of or the increase in the P status of the trees. It cannot be calculated in the same manner as the efficiency rate of N. This can however be done with drippers and hydroponics. With other systems supers is applied once or twice in a period of 5 to 7 years. There is also no relation between the mass of P applied and the leaf status or between the concentration P in the soil and that in the leaf. Banded P increase the P status of the leaves on average by 0,02 to 0,04% (from 0,11 to 0,13 or 0,15) but will be able to maintain it at a sufficient level form years ahead. Such an application will not raise the P status to 0,25%. The effect is not dramatic but long lasting.

P should be applied continuously at low concentrations when drippers of hydroponics are used.

In sandy soils a dramatic effect is noticed after an application of potassium. The potassium status of the trees increases almost immediately (Coetzee, 1977). With clayey soils the reaction on applications of potassium is slow (Figure 17). Sometimes the reaction is only a slow down of the decline in the potassium status (Figure 18).

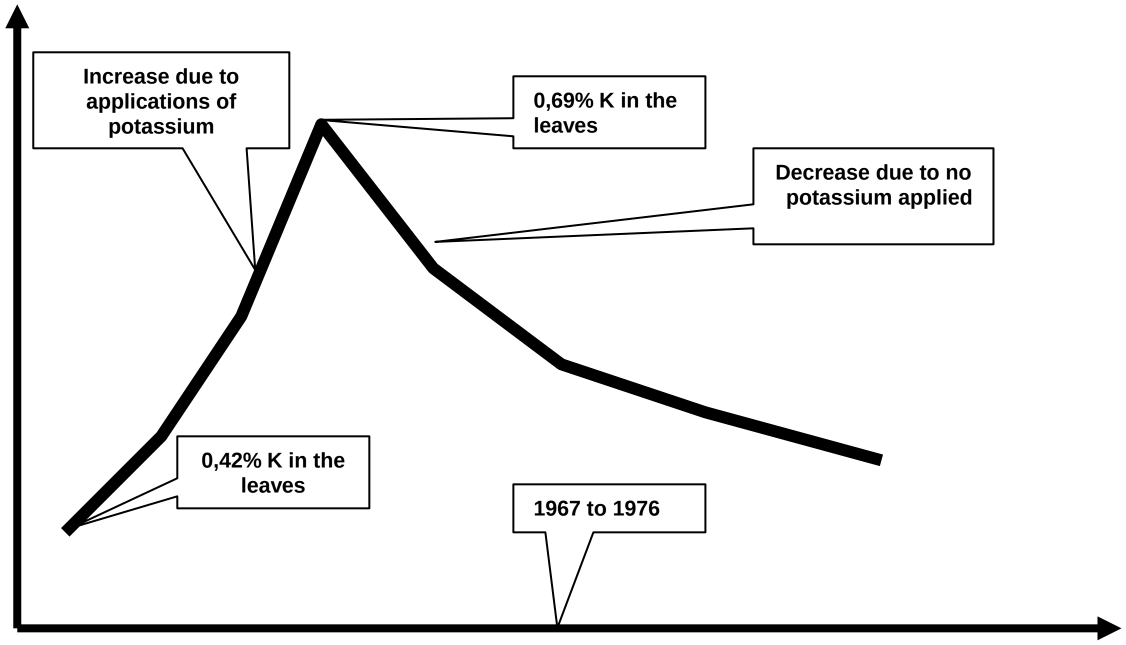

Figure 16. The quick responds in the potassium status of the leaves after applications or withdrawal of potassium in sandy soils.

Another useful evaluation of the potassium status is to consider the potassium saturation of (%K) and the mass of K available in the soil (Table 67). The evaluation must determine if the soil contains at least 3 to 4 times the mass of K that is required by one crop. For example a crop of 150kg fruit per tree is expected. At a spacing of 7x6m only 22mg K/kg soil is required. At an efficiency rate of 25% 88mg K/kg soil will satisfy the requirement. Compare that with the soil analyses report. If the soil contains less than the required 88mg then an application is essential.

The %K is calculated by expressing K as a percentage of the total concentration of cations. (Chapter 26 just after Table 66). The purpose will be to keep the K saturation between 5 and 7,5%.

If the soil contains enough potassium but the K status in the leaves is low, other methods than soil applications need to be used to increase the status. Foliar sprays or frequent applications at low concentrations can be tried (See Chapter 4 Table 15). This can easily be done with drippers and hydroponic systems.

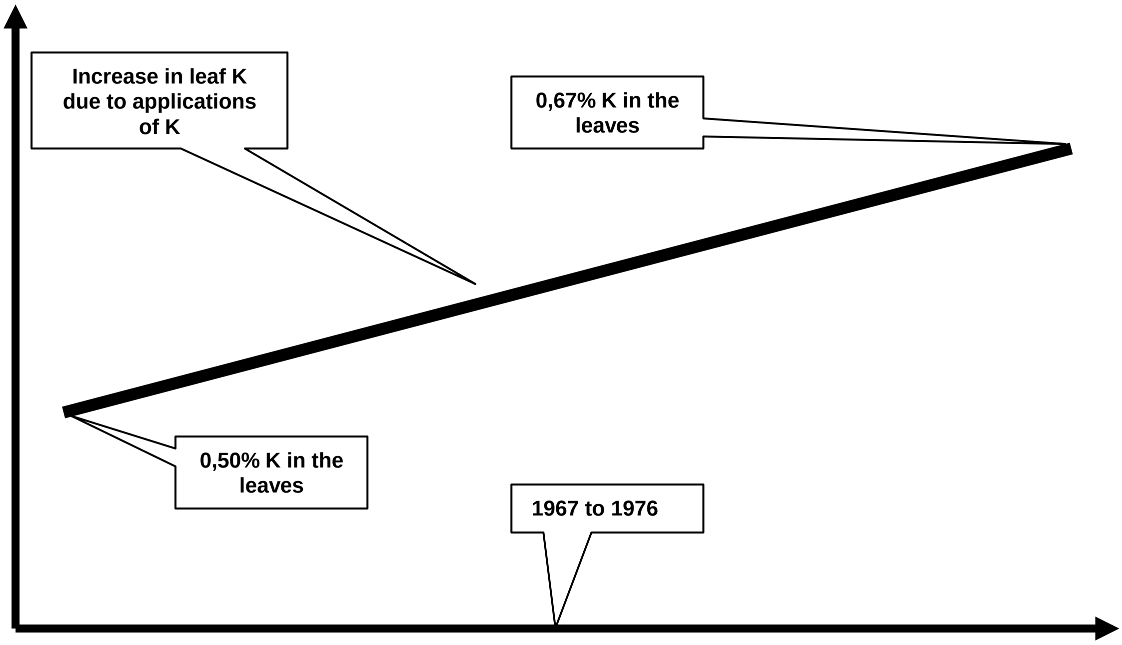

Figure 17. The slow responds of the potassium status of the leaves on application of K to a loamy soil.

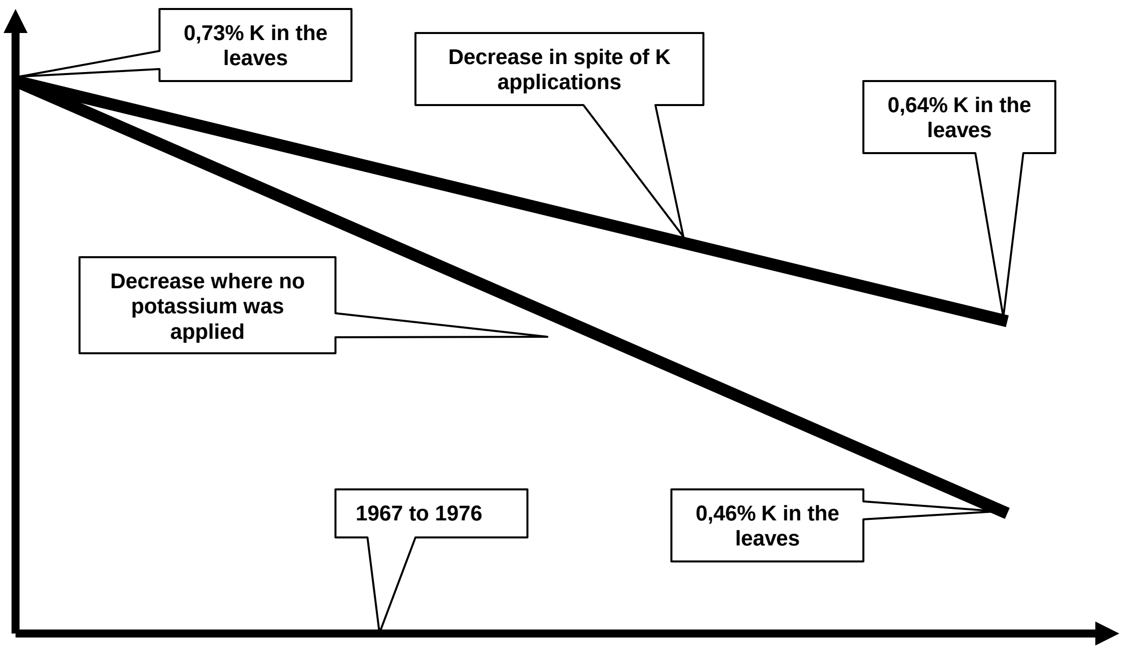

Figure 18. The masked responds of the leaf potassium status on applications of potassium to silty and alkaline soils.

Applications of calcium are based on the calcium saturation of the soil (just following Table 66) and the time when a calcium deficiency will impact the most on quality (cell division). In alkaline and neutral soils, calcium is applied as calcium sulphate (gypsum) in August or through the drippers as calcium nitrate from August to October. When the pH needs correction, liming will also supply Ca.

Applications of magnesium are based on the same approach as that of potassium.

Evaluate the leaf status, calculate what is available in the soil and then decide how to correct or maintain the magnesium status. Soil applications and/or foliar sprays can be used. Some waters contain enough magnesium to satisfy the entire requirement of the trees. Do not allow the magnesium status to drop below 0,20%. Once at such a low level it will take time to raise the level to normal. Remember that applications of potassium will suppress the absorption of magnesium. Keep an eye on the magnesium status when foliar sprays with potassium nitrate are done.

Sulphur is evaluated on the leaf content, the concentration of S in the water and how much S is applied indirectly by other fertilisers. On acidic sandy soils sulphur needs to be applied annually.

The application rate of fertilisers for commercial orchards should never be based on average tree age or tree size. It can only be used as a starting point when no other information is available.

- Times of application

Applications of fertilisers at the incorrect time can reduce the value of leaf analyses but if such information is not available, it will lead to total misinterpretation of the results. For example if N was applied shortly before the leaves were sampled, the high nitrogen status will indicate a too high application rate, which will be completely the wrong deduction.

Therefore supply the actual mass and time of the fertiliser's applications to the person who must compile a fertilisation program.

Application times are synchronised with the phenology of the trees in order to optimise profit. However, for some elements and treatment alternative times may be used (Table 76).

When a serious deficiency arises, it is always a sound policy to correct that before blossom. The trees already start in May with preparations for the new crop. Any deficiency during that period will have a serious impact on profitability. An important consideration with early applications is that it must not have a detrimental effect on the current crop.

Table 76. Alternative times of application of foliar sprays on citrus.

Element or product	Preferred time	Alternative times
Urea	Pre-blossom	No alternative
Urea	October	November to January except where colour is a problem then not later than November.
Urea on Satsuma and Shamouti	Post harvest	No alternative
Potassium nitrate	Pre-blossom	No alternative
Potassium nitrate	November	After fruit drop to January except where colour is a problem then not later than December.
Potassium nitrate	Post harvest	Only for satsumas or Shamouti. No alternative
Potassium nitrate	August or September	Up to January but the earlier the better
Potassium formulations containing no available N	August or September	Up to January but the earlier the better
Magnesium nitrate	Pre-blossom	No alternative
Magnesium nitrate	October	November to January.
Magnesium formulations containing no available N	August or September	Up to January but the earlier the better
Copper suspensions	Pre-blossom	On mature fruit.

Copper solutions	Pre-blossom	When little wind scaring is expected.
Manganese	October	November to April.
Zinc	October	November to April.
Boron	October	November to April.
Molybdenum	October	November to April.

- Methods to apply fertilisers

Drippers

The method used to apply the fertilisers will depend on the irrigation equipment available. With single line drippers, it is essential to apply the fertilisers with every irrigation. The frequency of applications will be determined by the volume of water that can be held in the root zone and the requirements of the trees. If the tree requires 75litres water per day and the root volume can hold 10 litres, then water must be applied 8 times per day. Nutrients must be applied with each irrigation.

The same principles are applicable when double line drippers are used. The volume of soil treated can however be so large that water need only to be applied once or less per day. With double line drippers at least one application of fertilisers should be done every week. If the soil contains less than 5% clay daily irrigation will most probably being required with double line drippers.

The EC of the nutrient solution must be increased with both double and single line drippers during rainy days or time with a low evapotraspiration rate. The mass of nutrients applied during sunny days must be maintained during rainy wheather.

Fertilisers should be applied during 90 to 100% of the duration of an irrigation cycle.

Another important issue is that the EC of the nutrient solution must be kept constant and any major variation over a short period must be avoided. A special cycle to clean the root zone is not a good idea. To keep the EC constant the concentration of one element (e.g. potassium) must be reduced when the concentration of another one (calcium) needs to be increased. For example when the requirement for N is high during spring, the concentration of K can be reduced to keep the EC constant. When more K is required during early summer, less N and Ca can be applied to facilitate the higher K concentration without changing the EC.

Gypsum but not lime, can be applied in small basins below each dripper to supply Ca and S. Lime will precipitate elements like P, Fe, Cu, Mn and Zn.

During fertigation the salts including the micro-nutrients will move to the outer perimeter of the wetted zone. This can be a hazardous situation when the pH of this zone of accumulation drops. At a lower pH more micro-nutrients like copper will dissolve and can reached toxic concentrations. It is therefore advisable to apply Cu, Mn, Zn and B at rates of 20-25% of the optimal concentration in nutrient solutions and supplement it with foliar sprays. Perhaps iron can be excluded from this list.

The pH of the root zone can be controlled by changing the ration of NO_3:NH_4. Lime is not soluble enough to be used in drip systems. Hydroxides can not be used due to the high pH (>9,00) that might damage the roots.

Microjets

Some of the fertilisers can also be applied through the microjet system. Fertigation with N, K, Mg, S, Fe and B can be done successfully through the microjets. Calcium can also be applied with success but not P.

When N, Mg and S fertilisers are being applied through the water, the fertilisers should be introduced during the last quarter of the irrigation cycle followed by just enough water to clean the system. Do not split the applications too much or apply fertilisers with each irrigation. Follow the guideline in Table 10.

However, to improve the efficiency of potassium applications, small dosages of 100g KCl per tree (or 100mg K per litre water) can be applied during the entire length of the cycle during September to December until the recommended dosage is applied (Table 15).

Mechanical and applications by hand.
Mechanical or applications by hand are based on the same principles. Splitting of N and K fertilisers is done based on the clay content of the soil (Table 10). Phosphates must not being broadcast but banded (Figure 5).

The major advantage of mechanical and hand applications are that the cheapest type of fertilisers can be used.

Goals
The main purpose of a good fertilisation program is to optimise the concentration of all the nutrients. Once this is obtained, fertilisation will not be the reason for suboptimal yields. Certain factors cannot be controlled, but with a balanced nutritional status, at least one variable is under control. With an optimal nutrient status, the trees can survive adverse cold, heat or drought conditions much better. Once the optimal status is obtained, fine tuning can be used to manipulate the trees.
The second aim is to obtain an optimal nutrient status at the lowest cost. By monitoring the inputs (fertilisers) and results (leaf analyses and production) only those elements that are in short supply need to be supplemented. With microjets it can mean that only N and Zn need to be applied.

The third aim is to produce quality fruit that can withstand packing and handling the best in order to give the consumer value for money.