## Leaf analysis as a basis for fertilization scheme

Leaves to be sampled: one leaf per spur, which does not carry a fruit. Sampling timing: in the middle of summer. In Chile it takes place between January 15th and February 15th.

## Critical levels

Table 1: nutrients levels and their interpretation for almond trees

| Element | Symbol | Unit | Values found (on dry weight basis) | | |
|---|---|---|---|---|---|
| | | | Deficient | Adequate | Excessive |
| 1. Nitrogen | N | % | < 2,0 | 2,2 - 2,5 | > 2,7 |
| 2. Phosphorus | P | % | < 0,1 | 0,1 - 0,3 | |
| 3. Potassium | K | % | < 1,0 | 1,4 - 2,5 | |
| 4. Calcium | Ca | % | < 2,0 | 2,0 - 4,0 | |
| 5. Magnesium | Mg | % | < 0,25 | 0,25 - 0,50 | |
| 6. Zinc | Zn | ppm | < 15 | > 18 | |
| 7. Manganese | Mn | ppm | < 20 | > 22 | |
| 8. Iron | Fe | ppm | | 120 | |
| 9. Boron | B | ppm | < 25 | 30 - 65 | > 85 |
| 10. Copper | Cu | ppm | < 3,0 | > 4,0 | |
| 11. Chlorine | Cl | % | | | > 0,3 |
| 12. Na | Na | % | < 0,20 | 0,20 - 0,25 | > 0,25 |

## Deficiency and excess symptoms of the main nutrients, and correction recommendations

## Nitrogen (N)

### Deficiency symptoms

Nitrogen deficiency is manifested at the beginning of the growth season, by a slight chlorosis, accompanied by a reduction in the growth of the twigs. In autumn the senescence starts earlier than normal, the leaves turn yellow, followed by early exfoliation. However, drought conditions produce the same symptoms. Nitrogen deficiency is difficult to diagnose since the trees in the orchard resemble each other.

### Correction of N deficiency

Nitrogen deficiency is corrected by fertilizing with a nitrogen-carrying fertilizer, either by soil application or by fertigation.

## Phosphorus (P)

### Deficiency symptoms

Phosphorus deficiency is rather uncommon. It does not present characteristic symptoms, but highly P- deficient trees show reduced growth and smaller than usual leaf size. P deficiency occurs when leaf contents is smaller than 0.1% of P in dry weight. Its soil availability depends on the soil pH. For example, at very acidic solutions (pH 0–2) it is found as $H_3PO_4$; at pH 2–7, as $H_2PO_4^-$; If the pH increases from 7–12, the ion $HPO_4^{-2}$ will predominate and pH >13, it will become $PO_4^{-3}$. This kind of deficiency has not been detected in Chile.

### Correction of P deficiency

It is corrected by applying any phosphorus- carrying fertilizer to the soil. In case that the P leaf levels are less than 0.1% on dry weight basis, phosphoric acid ($H_3PO_4$) can

be applied by fertigation.

## Potassium (K)

### Deficiency symptoms

Similar to other stone fruits (like plums, peaches and nectarines) potassium deficiency is not common in Chile, and if it exists, it resembles nitrogen deficiency. The new K-deficient leaves show symptoms at the beginning of summer. They become discolored, and both leaves-size and the branches length are reduced. Under mild K deficiency, no clear symptom is evident, and only foliar analysis can detect it. This is called "hidden deficiency". Potassium deficiency is definitely related to tree roots problems. In more vigorous buds the margin of the leaves can be necrotic and the size of the fruit decreases.

### Correction of K deficiency

Potassium deficiency is corrected by soil application of granulated potassium nitrate ($KNO_3$), potassium sulphate ($K_2SO_4$) or potassium chloride (KCl). Sprays can also be made with potassium nitrate ($KNO_3$), in doses of 10kg / 1000L of water. Potassium chloride (KCl) should not be applied by spraying to young trees, due to their susceptibility to scorching. Alternatively, any soluble potassic fertilizer, or NPK, can be applied by fertigation.

## Calcium (Ca)

### Deficiency

Calcium deficiency has not been detected in almond trees in Chile.

## Magnesium (Mg)

### Deficiency symptoms

Magnesium deficiency can be be associated with low pH (acidic) soils. Symptoms appear in the middle or late summer. The basal leaves, especially on vigorous branches, become chlorotic at their apex and edges, these leaves show premature senescence. Magnesium deficiency is rather uncommon in Chile.

### Correction of Mg deficiency

Magnesium deficiency can be corrected by applying highly soluble magnesium sulfate ($MgSO_4$) by fertigation. Alternatively, trees can be sprayed at the beginning of the growth season with magnesium nitrate $Mg(NO_3)_2$.

## Zinc (Zn)

### Deficiency symptoms

Zinc deficiency occurs when chicken manure has been used continuously, and/or when soil pH is alkaline, above 7.5. The symptoms appear at the beginning of the growth season. Flowering and development of the vegetative buds is delayed. When the deficiency is severe, the branch tips die ("die back"), the leaves are small and pointed ("Little leaf"), forming a rosette. When the deficiency is less severe, the leaves have a slightly smaller than normal size, and show interveinal chlorosis. When these leaves are tender, the margins can be rolled. The size of the fruit is markedly reduced,

and so does their quality. In plantations in sandy soils this deficiency is manifested. Zinc deficiency is rather common in almond trees in Chile, especially- in plantations growing on sandy soils.

### Correction of Zn deficiency

Can be corrected by spring foliar spray of zinc sulphate ($ZnSO_4$) at concentration of 0.3% (300g / 100L of water). In case that this solution must be neutralized pH wise, it is necessary to prepare the following solution: take 1kg of caustic soda (NaOH), dissolve it in 1 liter of water, then, take 30ml of this last solution and add it to 100L of the $ZnSO_4$ solution. Alternatively, spray the same $ZnSO_4$ solution, without neutralizing it, in the autumn, before leaf fall.

## Manganese (Mn)

### Deficiency symptoms

Manganese deficiency is uncommon. When it occurs, the leaves are chlorotic, similar to the deficiency symptoms of nitrogen. Small chlorotic zones show on the leaves, with a mottling pattern that resembles zinc deficiency. Mn deficiency does not affect fruit size.

### Correction of Mn deficiency

Manganese availability is pH dependent, so alkaline soils must be acidified by applying sulfur (S) to the soil, around the tree. Another acidification method is to apply sulfuric acid ($H_2SO_4$), in a controlled way, by fertigation, at rates of 18-25

kg/ha/year. Such soil acidification also increases the availability of zinc.

## Iron (Fe)

### Deficiency symptoms

This deficiency is associated with high pH soils. Iron deficiency occurs sporadically. When it occurs, the leaves become chlorotic at the beginning of the growth season, then they turn completely yellow. This chlorosis may disappear as the season progresses. In severe cases, the chlorotic leaves show scorching, and then they abscise.

### Correction of Fe deficiency

It is corrected by lowering the soil pH, by acidifying it with sulfur (S), applied to the soil, around the tree. Another acidification method is to apply sulfuric acid ($H_2SO_4$), in a controlled way, by fertigation, since iron is pH dependent.

## Boron (B)

### Deficiency symptoms

Terminal branches show scorching, they then present "die back". In the most vigorous branches, the apex and the edges become necrotic. Their bark cracks and becomes corky. This corky appearance takes place with the leaves too. On the next year the buds that are close to the affected area produce twigs with the appearance of a rosette. Fruit shows gummosis (it exudes resin) to the surface of the shell. In November–December (Southern Hemisphere, equivalent to May-June in the Northern

Hemisphere) there is abundant fruit drop. The leaves are smaller than usual, they curl upwards and tend to drop.In severe cases, a total loss of the harvest may occur. Fruit size is reduced.

### Correction of B deficiency

Boron deficiency is corrected after the harvest, by spraying the foliage with any product containing high concentration of boron, such as boric acid, and sodium octaborate, known as the product '*Solubor*' (1kg / 1000L of water). Most effective spraying takes place when there is enough young tender foliage. This treatment will exert its effect only in the next season. Another correction method is by soil application of Borax (11% B) at 50 kg/ha. Alternatively boric acid can be applied by fertigation.

## Copper (Cu)

### Deficiency symptoms

The symptoms of copper deficiency appear in the summer. Then, the terminal leaves become chlorotic, then they scorch and drop prematurely. The terminal parts of the branches show "die back". The tree looks shrubby. The bark of the trunk turns dark and rough. In the cultivar '*Non Pareil*' , strong gummosis (resin exudation) shows before bud break.

### Correction of Cu Deficiency

When foliar analysis indicates a value lower than 4 ppm on dry weight basis, and/or

when clear symptoms show up, this deficiency must be corrected. Correction is done by soil application of copper sulfate ($CuSO_4$) at 2kg/tree, or Cu-EDTA, at 300g/tree. Cu deficiency can be corrected also after harvest.

**Chloride ($Cl^-$) and/or sodium (Na) Toxicities**

Excessive chloride and excessive sodium provoke similar symptoms, such as leaf-tip chlorosis and necrosis ("tip burn"). The severer the toxicity, the larger the necrotic area, the climax normally takes place towards the end of the trees' activity season. A leaf analysis must be performed in order to find out which is the element that causes these symptoms. Contents of chloride and sodium greater than 0.3% and 0.25%, respectively, are considered excessive.

It is advisable that before planting, both the soil and the irrigation water, should be analyzed. There are guidelines that define the values of the analytical parameters to evaluate the risk that may take place for different fruit trees, for both the soil and the irrigation water.