



The effects of soil characteristics on the mineral nutrition of blueberry tree

Leaf analysis as a basis for fertilization scheme

Sampled tissue: Newly expanded leaves of branches with fruits.

The most advisable sampling time in the Southern Hemisphere is between December 15 and January 15, which is equivalent to June 15th to July 15th in the Northern Hemisphere.

Leaf analysis levels and their interpretation

Following, Table 2 and Table 3 show the nutrients levels and their interpretation, for High Blueberries ("Highbush") and Rabbit Eye ("Rabbiteye"), respectively.

Table 2: nutrients levels and their interpretation for High Blueberries ("Highbush") (on dry weight basis)

Element	Symbol	Unit	Values found		
			Deficient	Adequate	Excessive
1- Nitrogen	N	%	< 1,70	1,80 - 2,10	> 2,5
2. Phosphorus	P	%	0,10	0,12 - 0,40	> 0,80
3. Potassium	K	%	0,30	0,35 - 0,65	> 0,95
4. Calcium	Ca	%	0,18	0,40 - 0,80	> 1,0
5. Magnesium	Mg	%	< 0,08	0,12 - 0,25	> 0,45
6. Zinc	Zn	ppm	20	30	> 80
7. Manganese	Mn	ppm	23	50 - 350	> 450
8. Boron	B	ppm	20	30 - 70	> 200
9. Copper	Cu	ppm	5	5 - 20	> 100
10. Sodium	Na	ppm	0,10	0,12 - 0,20	> 0,30



Table 3: nutrients levels and their interpretation for Rabbit Eye Blueberries ('Rabbiteye') (on dry weight basis)

Element	Symbol	Unit	Values found	
			Deficient	Adequate
1- Nitrogen	N	%	1,20	1,70
2. Phosphorus	P	%	0,08	0,17
3. Potassium	K	%	0,28	0,60
4. Calcium	Ca	%	0,24	0,70
5. Magnesium	Mg	%	0,14	0,20
6. Zinc	Zn	ppm	10	25
7. Manganese	Mn	ppm	25	100
8. Boron	B	ppm	25	70
9. Copper	Cu	ppm	12	30
10. Sodium	Na	ppm	<5	10

Blueberries lack root hairs and have a shallow root system. They are susceptible to both drought and to waterlogging, therefore controlling soil moisture is essential for appropriate development of this plant. This species has a low requirement of fertilizers, and excessive fertilization provokes browning of the tips and the edges of the leaves' blades.

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

The fertilizer requirements of this species are very low, much lower than most fruit trees. Continuous application of fertilizers, at low doses, is more efficient than at high doses. In young blueberry, excessive fertilizers may damage the plants, by injuring their root systems, even if the doses are low. The reason is that their roots lack root-



hairs. For this reason, it is not recommended to perform localized applications. Foliar chlorosis can be induced by the deficiency of various nutrients, hence, the identification of the actual cause must be determined by leaf analysis.

Nitrogen (N)

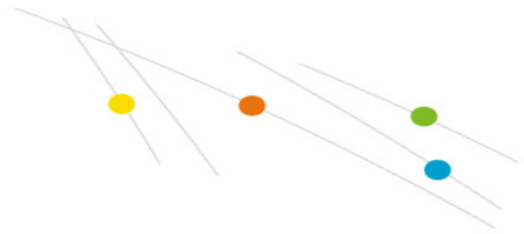
Deficiency

Application of high doses of nitrogen can increase its level in the leaves to about 2.5% of dry weight, which can have detrimental effects on plant's productivity. It is recommended to distribute its application throughout the growth season. This nutrient is of greatest annual requirement, and its consumption depends on plant's age. Nitrogen deficiency provokes reduced growth and the appearance of interveinal chlorosis. As the chlorosis progresses, and is accentuated, the leaves' edges show scorching, followed by leaves abscission.

Low-vigor plants present pale leaves, and early leaves' abscission. But this symptom may be due to deficiencies of nitrogen (N), manganese (Mn), iron (Fe), and to a lesser degree- of potassium (K) and boron (B). Excessive nitrogen makes the plant more susceptible to frosts.

Correction of N deficiency

Ammonium nitrate (NH_4NO_3), is a nitrogen carrier, recommended for blueberries, thanks to its soil acidifying effect. Alternatively, urea can be used in traditional



irrigation. Blueberry can take up nitrogen in both forms of ammonium (NH_4^+) and nitrate (NO_3^-). Some researchers point out that application of half the nitrogen rate at bud-break, and the other half at petals drop, could increase the yield.

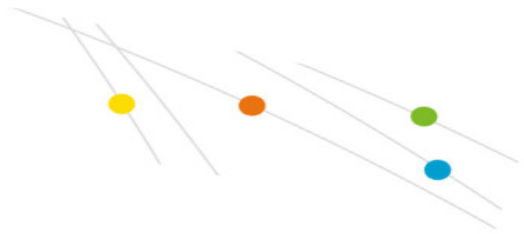
Phosphorus (P)

Deficiency

Phosphorus deficiency is rather uncommon in Chile. Relatively young soils of the "Trumao" type, with variable contents of free aluminum (Al), are likely to show P deficiency. P deficiency is manifested by chlorosis, and newer leaves are smaller and greener than normal, plant growth is reduced. There is a very low correlation between P contents of the leaves and of the soil, therefore, soil analysis is not recommended for demonstrating plants' P status. Excessive soil phosphorus can induce iron (Fe) deficiency that limits the development of the plant.

Correction of P deficiency

P deficiency is corrected by applying phosphorus- carrying fertilizers to the soil, such as triple superphosphate or ammonium orthophosphate. Alternatively, fertigation can be used for application of water- soluble fertilizers like phosphoric acid (H_3PO_4), mono-ammonium phosphate (MAP), mono-potassium phosphate (MKP) or urea phosphate.



Potassium (K)

Deficiency

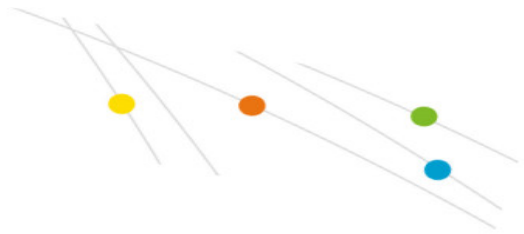
Low foliar levels of potassium may be related to acidic soils. Also, potassium content becomes lower with the age of the plant. It also suffers variations according to its fruit load, hence, highest K concentrations occur in young plants. There is a correlation between foliar and soil potassium. But high soil potassium aggravates the magnesium (Mg) deficiency, due to the known uptake antagonism between these elements.

Correction of K deficiency Potassic fertilizers should be applied only when plants' foliar content displays deficiency. In this case the following fertilizers are used: potassium sulphate (K_2SO_4) or potassium nitrate (KNO_3). They can be applied directly to the soil, or by drip fertigation.

Calcium (Ca)

Toxicity symptoms

Blueberries, like other species of the Ericaceous ones, are calciphobic, or acidophilic, and therefore, they are adapted to grow in acid soils and with low calcium content. This is reflected in the low contents of this element in the leaf tissue. Excessive calcium can produce toxicity. The variety "Highbush" has higher foliar Ca concentrations than the "Rabbit Eye".



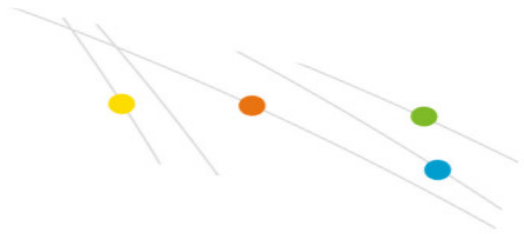
Deficiency

Blueberry is a species that is able to take up calcium (Ca). Deficiency symptoms include yellowing of the leaves' margins, especially of the young ones. Leaves situated at the branches' terminals may present some yellowish-green spots. In Chile, symptoms of calcium deficiency have not been observed. It has been observed that calcium levels of the soil are related to its pH levels. And plant's calcium content is related to its fruit load and to the nitrogen fertilization. Plants with excessive vigor show reduced content of calcium, which can be related to a dilution effect.

The concentration of calcium in the fruit influences its firmness, as well as its texture and harvest time. There is a close relationship between fruit's calcium content and its post-harvest life, particularly- its firmness. Fruit firmness can be increased with pre-harvest applications, as well as by post-harvest immersion of the fruit in a with calcium chloride (CaCl_2) solution at 0.5-0.8%.

Deficiency correction

Soil calcium can be increased with applications of calcium sulphate or gypsum, this neutralizes the exchangeable aluminum ("Trumaos"). Foliar applications of calcium chloride are not recommended, as they can produce phytotoxicity.



Magnesium (Mg)

Deficiency

Magnesium deficiency is almost always associated with sandy soils and/or with low contents of organic matter. In general, magnesium deficiency is closely related to low cation exchange capacity (CEC) of the soil. Also, excessive potassium applications reduce the availability of magnesium, which manifests itself by leaf chlorosis that appears late in the season. This chlorosis shows as interveinal reddening, curved leaves, defoliation, and some necrosis, accompanied by reduced growth.

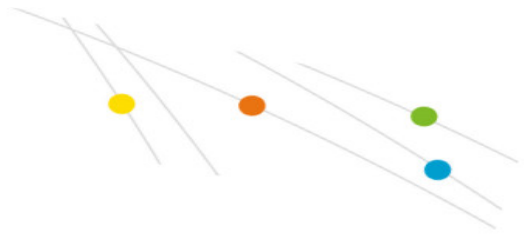
Correction of Mg deficiency

Magnesium deficiency can be corrected by soil application of granulated Sulpomag, and by fertigation with magnesium sulfate (MgSO_4), also called 'Epsom salt' or by fertigation with magnesium nitrate [$\text{Mg}(\text{NO}_3)_2$]. The latter product can be also applied by foliar spray. Good results can be expected when this spray is done when the leaves are young and tender.

Zinc (Zn)

Deficiency

Blueberry requires only small amounts of zinc, therefore, Zn deficiency symptoms are rather scarce. The plant grows well in acidic soils, in which zinc is easily available.



Excessive phosphorus (P) applications can induce zinc deficiency. Zn deficiency decreases the growth of terminal leaves.

Deficiency correction

With a zinc carrier (Zn), early in the season.

Manganese (Mn)

Deficiency

Manganese deficiency is common in neutral or basic pH soils, but soil with lower pH have significantly higher manganese availability to the plants. Blueberry takes up the manganese from the soil very efficiently, hence it is rare that Mn deficiency takes place. This easy uptake enhances Mn accumulation to high concentrations. Levels of up to 4,000 ppm (DW basis) have been reported, without incurring toxicity. However if it grows without available Mn, the leaves develop chlorosis.

Mn deficiency correction

To solve manganese deficiency, it is recommended to acidify the soil. Alternatively, the plants can be sprayed with a Zn- carrier, when it has tender leaves.



Iron (Fe)

Deficiency

As in the case of manganese, Fe availability is associated with pH- neutral and alkaline soils. Fe deficiency is also induced by high content of phosphorus in the soil. It is manifested by leaf chlorosis.

Fe deficiency correction

Fe deficiency can be corrected by acidifying the soil, by using an acidifier, like sulfuric acid (H_2SO_4), or phosphoric acid (H_3PO_4), applied by fertigation. Elemental sulfur (S) can be applied to the soil. Alternatively, a ferric chelate could be used.

Boron (B)

Deficiency

Boron deficiency negatively affects the flowering, and therefore reduces fruit production and the yield. B deficiency provokes slight leaf chlorosis. Boron excess produces leaf scorching and necrosis.

Deficiency correction

Boric acid, sodium octaborate ("Solubor") and/or borax can be applied by fertigation.



Alternatively, foliar spray can be done with a boron carrier, like "Solubor", and "Speedfol[®] B SP".

Other Considerations regarding Soil Properties

pH

The development of blueberry plants is limited in soils with pH above 7. In such alkaline-pH soils, plant development limitation, results from excessive uptake of sodium (Na) and restricted uptake mainly of phosphorus (P), zinc (Zn) and iron (Fe). But similar inhibition also happens in very low-pH soils, due to excessive manganese (Mn). The best development of the plant, according to some authors, occurs with pH levels between 4.0-5.2, or 4.5-4.8. Most varieties of "Rabbit Eye" blueberries thrive in soils with pH of 4.0-6.0. pH levels higher than those indicated above, produce a nutritional imbalance, causing ferric chlorosis. These high pH values can be controlled by soil acidification, with elemental sulfur (S) or sulfuric acid (H_2SO_4). It is recommended to take this measure before planting. When applying sulfur (S), it must be worked into the soil, to avoid too high local S concentrations in the soil. As a general recommendation, it is advisable to annually check the pH of the soil, since the use of certain fertilizers can increase it.

Organic matter

In soils with a low content of organic matter, mulching the soil with pine sawdust, improves blueberry growth, especially when soils' pH is above 6.0. This conifers sawdust should be supplemented with nitrogen, to stimulate microbial activity, and



achieve a faster decomposition of the sawdust, while avoiding "nitrogen hunger".

Other factors that influence nutrition

Light

Light availability is highly important in blueberry. It has been shown that in the variety "Rabbit Eye", the percentage of colorful fruits, and their size are directly related to the amount of light received by the plant's top. Both the number of leaves and their spatial distribution play an important role in achieving better sunlight interception (winter and summer pruning). Photosynthetic efficiency rarely exceeds the 2% level in these plants. Among the most important factors that affect it, are adequate water supply, and the light related to the density of the plant tops, since the most shaded parts only achieve 50-60% of the maximum photosynthesis. Also the fruit load affects the photosynthetic efficiency, since generally the higher the fruit/leaf ratio, the higher the photosynthetic efficiency.

Water

Blueberry is very sensitive to both deficit, and excess in water availability, hence, water can become a limiting factor on plants' development and production.