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Identifying and Managing Soil & nutrient Issues for Blueberries On The North Island New Zealand Peat-lands

Key Words: Blueberry, Peat soil, Allophane Volcanic Ash, pH, Soil Acidity, Aluminium Toxicity, Iron & Phosphorus uptake, Redox, Bicarbonate, Nitrate Reductase, Ammonification, De-nitrification, Fertiliser Choice, Waikato, New Zealand.

Abstract. Popular wisdom for growing Blueberries usually puts top of the list that they require an low pH acidic soil type and that the use of Lime and non-acidic Nitrate fertilisers should be avoided. However several of the North Island New Zealand Peat soils are a mixture of Organic matter and Allophanic Volcanic ash & Pumice and the organic acids associated with the Organic matter is dissolving the Volcanic materials resulting in very high levels of Free aluminium [25 – 250ppm KCl extractable Al]. Using historical grower data; this paper investigates the magnitude of the problems associated with the free aluminium on the various soil types. And also considers the question of when is it appropriate to use Lime and Non-acidic Nitrogen products and at what rates.

The USA has published significant data on blueberry nutrition, however much of it is related to sandy mineral soil types. The existence of Peat Bogs at similar latitudes to the Waikato New Zealand (NZ) are quite rare and the close proximity to recently active andesitic volcanos makes this region almost unique for blueberry growing soil types.

Blueberry growing in the Waikato region Encompasses the Peat-lands centred around Ohaupo & Gordonton also on acidic sands and some volcanic sandy loams in the southern Waikato. To a lesser extent blueberries are grown in Northland where there are pockets of peaty soils.

We have used our blueberry soil & leaf analysis data base as a basis for statistical research in order to identify key issues affecting productivity and also to quantify the differences between soil types. We present here our results along with a rationale for dealing with these matters. This study is specific to the soil types detailed below; other soil types may need different handling.

Soil Types:

1) Sandy Soils predominated by Horitu Sandy Loam. Parent material Rhyolite Alluvium mixed with Andesite ash. Because these soils are so very different to the peat soils we removed their data from this particular study.
2) Organic Soils
   a. Mellow Peaty Loams [Peat & Volcanic ash]
   b. Intermediate Peaty Loams [Piako, Kaipaki, Ruakaka, One tree point]
   c. Acid Peats [Rukuhia, Tokaanu.]

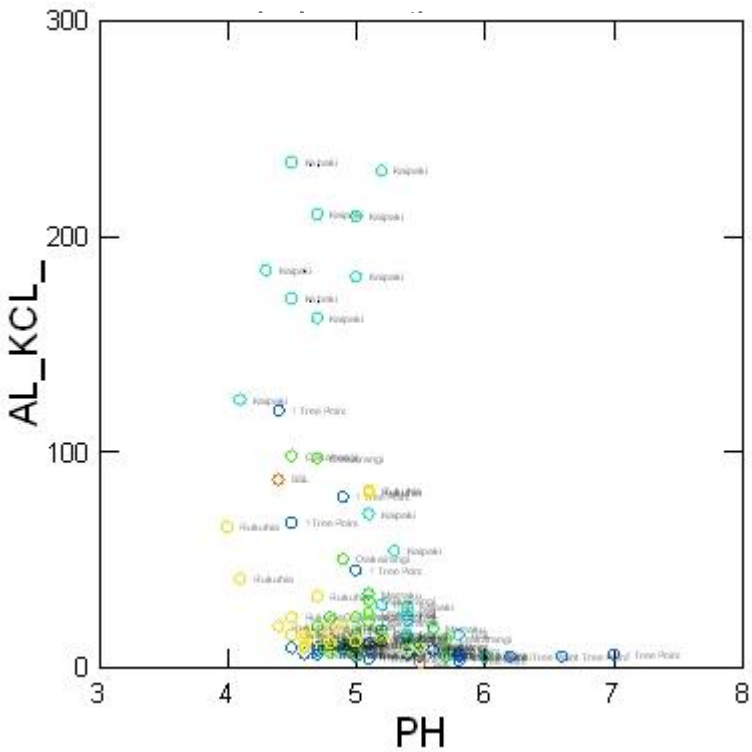
The word mellow is somewhat misleading because with the addition of volcanic ash there are some advantages but there are also distinct disadvantages:

a) In the positive the admix of volcanic ash gives these soils a pH buffering so that naturally the pH can be 5.5 to 6.2 and the soil is less prone to nutrient leaching.
b) In the negative, the combination of acid forming organic matter and high allophanic volcanic ash [typically >70% aluminium oxide] results in high soluble “free” aluminium in the soil solution.

Table 1:	Soil Analyses Mean Values Ranked Red Lowest & Green Highest. Sorted by Available Iron							
Soil Type	**SMP Buffer pH Mean**	**pH (1:1) Mean**	**Mehlich Al (ppm) Mean**	**KCl Al (ppm) Mean**	**Calcium (ppm) Mean**	**OM% (LOI) Mean**	**Carbon% (Dumas) Mean**	**Iron (ppm)**
Ardmore Peaty Loam [A]	5,7	5,7	1523	25	1168	44,3		75
One Tree Point Peaty Sand [On]	5,4	5,2	1103	16	2881	43,1	23,33	87
Otakairangi Loamy Peat [Ot]	5,0	5,0	1268	25	2586	48,3	25,66	111
Kaipaki Peat Loam [K]	5,0	4,9	1838	142	1300	46,5	27,93	157
Horitu Sandy Loam [H]	6,2	5,4	1192	20	968	8,3	4,10	204
Rukuhia Peat [R]	4,7	4,7	755	26	2450	77,6	42,55	213

The DSIR publication The Soils of North Island (1953) describes the Mellow Peaty loams as having Peat and Alluvium parent material. Whereas the Kaipaki Soil is classed as intermediate with the parent material of Peat and some alluvium with the term "some" suggests that there is less alluvium than the Mellow Peaty loams. However table one clearly shows that the Kaipaki soil has significantly higher Mehlich extractable aluminium, therefore the alluvium content will also be higher. No doubt the visual negative effects of the high aluminium levels on pasture growth disqualified this soil from being referred to as a "mellow" peat.

Fig 1 Soluble Aluminium Vs Soil pH



Aluminium toxicity:

The issues concerning Aluminium toxicity have not widely received due recognition, for example in the excellent publication "Fertiliser Use On Waikato Peat Soils" made no reference to Aluminium. However D Edmeads published a very helpful article in 1983 "Aluminium toxicity in New Zealand soils" in which the negative effects of soluble aluminium in clover was clearly proven with a close to linier result. Without doubt Blueberries have far greater tolerance for soluble aluminium than clover, but there are limits even for blueberries, however as far as we know this has never been evaluated.

When aluminium is in the mineralised form associated with sufficient Silica, Oxygen and other metals it forms various clay types which are beneficial for the retention of various nutrients in the soil. With non-volcanic clays the Si:Al ratio is high and the clays are Planar as flat two dimensional with glassy silicate layers safely sandwiching the Aluminium where it is stable and poorly soluble. This aluminium fraction we do not measure for it is not an issue.

Conversely when the Si:Al ratio is low as in certain volcanic ash soils and rain fall is high, then allophane clays are produced, these are non-planar (not flat) in form and are only moderately stable being readily dissolved by natural organic and synthetic acids (i.e. various fertilisers). With our soil analysis data we have an approximate estimate of the aluminium fraction associated with allophane using the Mehlich III extract of aluminium.

The harmful, soluble aluminium fraction that has been released from the allophanic clays is measured via the KCl aluminium extract. Using our Blueberry Grower soil data, we present the scatter plot Figure 1 which confirms the relationship between acidity and aluminium solubility with higher pH soils having low aluminium solubility. From experience we have found that ideally the KCl extract of aluminium should be less than 20ppm to be sure of healthy root growth. The light blue data points (Fig 1) are specific to the Kaipaki type soil and it can be see that when the soil pH is below about pH5.5 the release of soluble aluminium is significantly greater than for all the other soil types and this is due to the higher content of Allophanic Ash, as you will note from the Table 1 .. Mehlich extraction of aluminium.

With the exception of blue Hydrangeas there are no horticultural advantages with having free aluminium in the soil. Free aluminium strongly immobilises soluble phosphate by combining to form the mineral Strengtite which renders the phosphorus almost useless as a nutrient; this is because plants cannot acidify the root sufficiently to re-solubilise the phosphate so that it may be utilised. Therefore we expect to see that high soluble aluminium causes sub-optimal phosphorus uptake [affects include low flower numbers small leaves] and that is what is indicated by the scatterplot (fig 2).

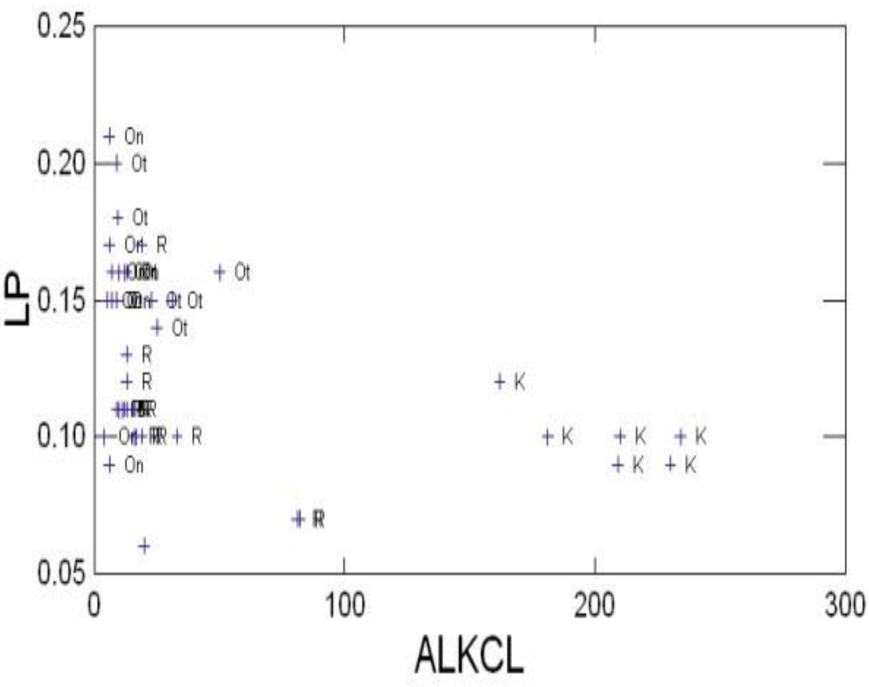
For the Kaipaki soils which are marked "K" gaining sufficient phosphorus uptake is a major issue. Hills Laboratory (Hamilton) quote the normal range P level for Blueberries as being between 0.12 & 0.40 % therefore many of these results are below the normal range.

A second major issue on soils with high free aluminium follows the following scenario:

As plants transpire they draw water into the roots from the soil solution and along with this water goes the free aluminium. Nearly all plants including blueberries recognise and exclude aluminium as an unwanted element and in time aluminium accumulates on the root surface to the point of toxicity and root death ensues after which plant performance is severely restricted due to reduced root mass that limit both water and nutrient uptake.

Roots affected by aluminium toxicity are fairly easy to recognise as they have few fine roots and the surface usually exhibits a blackish colour. Clearly managing soluble aluminium should have high priority so that root health & mass may be maximised, then water & phosphate fertiliser efficiency can be optimised. Figure 1 and 2 above indicates that raising the soil pH to neutralise free aluminium should be advantageous, however there are other considerations, which we now discuss as issues concerning acidity & pH and iron uptake.

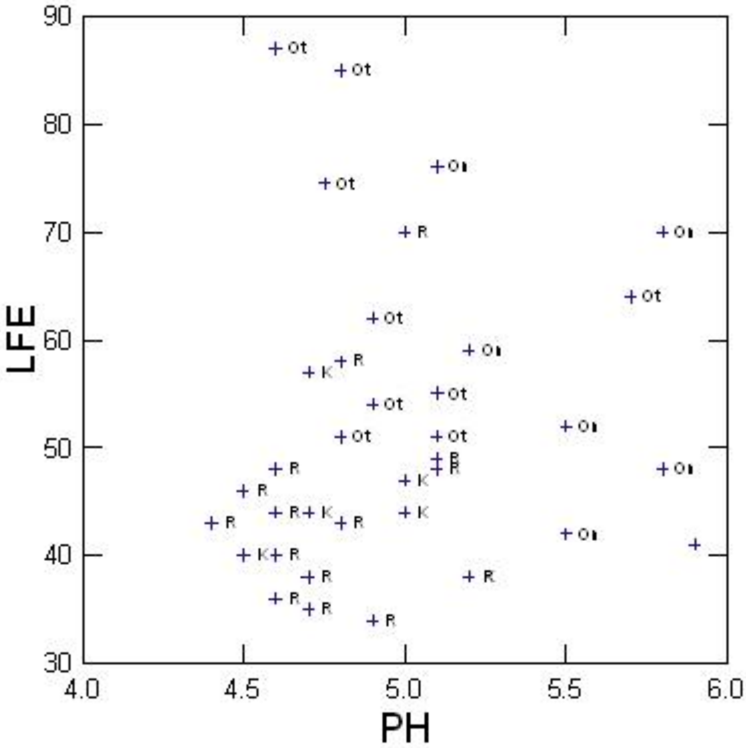
Fig 2 Leaf Phosphorus % Vs Soil Aluminium **(ppm KCl)**



Soil Acidity pH.

For growing blueberries the soil pH is the soil analysis value regarded by many as the most important part of the analysis and low pH values are normally considered advantageous. However the reason behind this is often forgotten and the key issue for blueberries is that they have a high requirement for high iron availability and for most soil types iron availability is greater at lower soil pH levels. This is due to the reduction of poorly soluble (Oxidised) ferric iron (Red/brown loams typical of Pukekhoe NZ) to the soluble ferrous iron (grey/green clays typical of Hauraki NZ). Considering the scatterplot Figure 3 "Leaf iron verses soil pH" **we do not see the presumed benefit of low pH** coming through to the uptake of Iron by the plants. Consider the Data points (Fig 3) marked "R" which refer to Rukuhia Peat. Those soils have the highest soil iron levels (see table 1) also the soil pH is amongst the lowest and yet iron uptake was deficient. Apparently there is another factor effecting iron uptake and to a greater degree than soil acidity. The reduction of iron is not only pH dependant but equally important is the soil oxygen potential (referred to in soil science as Eh or redox potential). Wet soils usually have low oxygen (low Eh) with high ferrous iron, which should result in good leaf iron uptake, but this is not always what we see. The key problem with overly wet soils is that when the soil oxygen levels become too low for aerobic respiration then anaerobic root respiration proceeds using different biochemical pathways and these generate various alcohols, which are damaging to the roots.

Fig 3 Leaf Iron (ppm) Vs Soil pH



Therefore to maximize root growth and to have good iron and phosphate uptake the soil needs to be moist for as much of the season as possible but also with good drainage so that the water table remains below about 500mm depth and this ensures adequate oxygen for healthy root respiration. The data presented in these plots also indicates that soil pH probably needs to be adjusted with a different target for each soil type and it is our aim to include these considerations in future soil analyses.

Fertiliser Choices:

Liming:

When Aluminium toxicity is a significant risk, then the neutralising of this aluminium takes highest priority and raising the soil pH through lime application is a tried and tested method. The basic principle of liming follows the following equation:

$$[\boldsymbol{Lime\ (CaCO_3) added\ to\ Acidic (excess\ H^+) Moist\ soil}]$$
$$= [\boldsymbol{Moister\ soil + Calcium + (1H_2O\ water) + (1CO_2\ Gas)}]$$

Therefore one $CaCO_3$ molecule will neutralise two H^+ ions. Put simply soil acidity is all about an excess of Hydrogen ions in the soil solution and raising the pH is the reduction of the H:0 ratio in the soil water. For a very easy to understand explanation of pH & soil acidity check the following link.

http://www.biosoil.co.nz/meaning-of-ph.html

If the above equation proceeds consistently completely then calculating the lime rate for the different soil types would be a very simple mathematical process. However it is very important that we take into account that a certain proportion of the reaction is incomplete, producing Bi-carbonate HCO_3 (especially in the presence of excess potassium or sodium) and this bi-carb has a strong interfering effect with iron uptake. In view of the importance of the iron issue we will usually cap recommendations lime or Dolomite application rates for mature blueberry bushes to a limit of 1t/Ha and in cases of severe aluminium toxicity we can recommend the Rorreson's Mag lime™ at a higher rate because, unlike Dolomite the magnesium content is not supplied as a carbonate but it is a finely ground silicate serpentine rock dust mixed with high quality calcitic lime . Therefore 1500 Kg/Ha of 30% Mag lime has the approximate lime value of 1,000Kg/Ha ordinary calcitic lime. The remaining Magnesium silicate has three key advantages:

1) It is a controlled release form of magnesium.
2) Increasing the silica to aluminium ratio should help to render the soluble aluminium harmless by forming stable clay minerals [probable but unproven].
3) Silicate minerals are strongly anti-Phytophora and this particular root disease is a major problem for blueberries.

Nitrogen Fertilisers:

The balance of having healthy leaves and sufficient new growth on one hand with excess strong non-fruiting wood on the other hand is very closely related to nitrogen inputs. There are a wide variety of nitrogen fertilisers that can be called upon (see table below) . When there are aluminium toxicity issues the fertiliser choices should be with products that cause the minimal acidification. This is very difficult because most ammonia based fertilisers have acidifying strong effects and this includes Urea for with the microbial produced enzyme urease, the decay of the urea molecule results in two Ammonium ions. Nitrate fertilisers on the other hand are generally not acidifying but using this source of nitrogen for blueberries presents another problem.

Research with Blueberries experimentally grown in hydroponic solution has confirmed that Blueberries are not equipped for taking up and utilising Nitrate nitrogen for they are better adapted for using ammonium. This is not surprizing for two reasons:

1) Blueberries are well adapted to acid soil conditions and Molybdenum availability is usually very low in acid soils. To utilise nitrate the plants need the molybdenum containing enzyme Nitrate reductase. Therefore even if the nitrate is taken up into the leaves, the plants cannot make good use of the nitrogen.
2) In wet acidic peat soils the Nitrate:Ammonium ratio is expected to be naturally low.

The trials referred to above were Hydroponic laboratory experiments with no influence of soil, biology or from soil/plant organic compounds. These are important factors which require that we are cautious when applying laboratory results to the real world, which is very much more complex.

Whilst acknowledging that the primary nitrogen input ideally should be in the ammonium form there may be some advantages in using a combination of ammonium and nitrate e.g. Calcium ammonium nitrate as a secondary nitrogen fertiliser source and the following characteristics should be considered:

1) Very few fertiliser compounds remain unchanged once they have entered the soil system and both Nitrate and ammonium are in a state of flux changing according to the soil's content of water, oxygen, acidity and biology. The reduction of Nitrate to ammonium is termed Ammonification, there is another transformation that is nitrogen wasteful, the process of de-nitrification where nitrogen is lost as gas. To put this gaseous loss in context we should also remember that up to 50% of the nitrogen in Urea fertiliser may also be lost as gas through volatilisation therefore under some circumstances gaseous loss with CAN may likewise be accommodated as a necessary evil. In more recent years there are now coated nitrogen fertilisers, which are thought to get around the problems of gaseous losses.
2) As previously discussed CAN has the lowest acidifying effect on the soil (see table below). Acidifying fertilisers should not be used without care, reasoning that just adding lime at the prescribed rate, for with blueberries we also need to keep lime inputs just to what is absolutely necessary to the bi-carbonate/iron problems.
3) The booklet "Fertiliser Use on Waikato Peat Soils" p24 states that it is proven that on peat soils, the greatest nitrogen loss is through leaching ammonium due to low cation affinity. Nitrate has a lower leaching loss because the peat soils have greater anion holding ability compared to cation storage. Therefore a dual product containing both ammonium and nitrate will supply immediately utilisable N as ammonium and in reserve; N in the form of nitrate which is can be held and modified within the soil.
4) Although the blueberries themselves are not likely to utilise any great amount of the nitrate fraction, it is still a source of nitrogen entering the orchard ecosystem being utilised by the grass sward in the roadways between the rows of bushes and mowing recycles the nitrogen in an organic form, which will be utilisable by the blueberries. The down side of this aspect is that fertilised weed growth among the blueberry bushes is a big issue.
5) In summary of the forgoing Nitrate questions I believe that limited amounts Nitrate containing fertilisers may be recommended in instances where there are significant Aluminium toxicity issues and increasing soil acidity needs to be avoided at all costs.

Table 1. Some nitrogen sources, their N content and the amount of lime required to neutralise their acidifying effect on soils.

Nitrogen source	N content (%)	Lime requirement*
Ammonium sulphate	21	5.2
Anhydrous ammonia	82	1.8
Ammonium nitrate	34	1.8
Urea	46	1.8
UAN solution	28–32	1.8
MAP	10–11	5.0
DAP	18	3.1
CAN	26	0.3–0.7

*Amount of pure calcium carbonate ($CaCO_3$) required to either neutralise the acid-forming reactions of 1kg N or the amount of $CaCO_3$ required to equal the acid-reducing effects of 1kg N.

Source: Glendinning JS, (2000) *Australian Soil Fertility Manual*, CSIRO Publishing, Collingwood, Victoria.

Phosphorus Fertilisers:

Di-ammonium Phosphate (D-A-P):

This is ideal for supplying some early season (Blueberry bud break) N & P whilst the soil is still cold and there is little biological release of organic nutrients. However the product is strongly acidifying and therefore rates of use should be low, there is little or no longevity.

Superphosphate:

This product is strongly acidic and the release properties are very fast with little longevity. We consider it to be unsuitable for Blueberries.

Fine Rock Phosphate Dust:

This this product has a 25% liming potential, possibly with no Bicarbonate produced. It is one of very few fertilisers that do not harm soil biology and that is very important when we consider the Blueberry Mycorrhiza root association. It is a long term fertiliser ideal for perennial crops on acidic soil types. Phosphate rock dusts contain Fluoride & Cadmium to varying degrees therefore Low Fl & Cd products are preferred.

Sulphur:

Elemental sulphur (Durasul)

Although certified organic, there are some distinctly anti-biotic properties. When moistened in the soil, with the help of Thiobacillus each atom of S will take 4 oxygen atoms from water and release 8 hydrogen atoms therefore it is strongly acidic.

Gypsum:

This product is pH neutral and has good controlled release of sulphate sulphur. It is ideal when there are clays in the soil for improving soil structure because of the calcium content. Because of the calcium care needs to be taken in balancing the Calcium to magnesium ratio.

Potassium:

Muriate of Potash:

The formulation of this natural mineral is very similar to table salt but in this case it is Potassium Chloride. Just saying the word chloride sets of alarm bells for many people, but why should it? Do we avoid table salt just because it contains chloride? No! We just take care not to use too much. In reality chloride is a very important plant nutrient needed in greater quantities than phosphorus. The key is to limit inputs according to crop tolerances which for Blueberries are lower than most other crops because of the strong reliance on soil microbiology. We find a limit of 80Kg/Ha/Year Muriate of Potash supplies enough chloride without harming the soil biology to any noticeable degree.

Sulphate of Potash:

This product is very important for blueberries supplying both sulphur and potassium. Like most fertilisers Sulphate of Potash is a salt, therefore take care not to apply whilst the soil is dry, otherwise the effects drought stress will be increased.

Trace Elements:

Copper:

On high organic matter soils copper is notoriously low and uptake is frequently deficient. With blueberry rust being a major issue, copper deficiency will not help the bushes produce their natural fungicides called phyto-alexins. The use of Copper hydroxide foliar sprays has two advantages.

1) The residues of copper on the leaves do prevent the germination of rust spores.
2) In autumn the copper on the leaves will fall to the soil and may be considered as a copper fertiliser.

Light annual dressings of copper sulphate in the winter fertiliser may be advantageous.

Iron & Manganese

There is little advantage in applying solid fertiliser for these two elements as there are usually plenty of these nutrients in the soil but uptake is blocked by either oxidation or competition with other ions. Therefore the use of good quality foliar chelates is our preferred choice of iron & manganese fertiliser.

Boron.

This element is often is short supply, however because there is a narrow band between deficiency and toxicity, we prefer controlled release minerals like Ulexite (Boronate 32).

Zinc:

Deficiency is possible but we have not yet identified any cases to date.

Nutrient Monitoring:

Soil analysis:

Regularity is critical so that fertiliser responses can be monitored. pH is a big issue therefore both ordinary and Buffer pH tests should be included. Soluble aluminium is a big issue therefore should be measured using the KCl extraction. The Olsen P test is not ideal for acidic soils and the Mehlich extraction is better.

If rock phosphate is used a reserve P test is needed such as the Bray II or Resin P test.

We are in the process of making soil analysis desired range values specific to soil type.

Leaf analysis:

This also is critical because the soil interactions with fertiliser are so complex we just cannot assume all is well because fertiliser was applied. Nutrients in blueberry leaves change throughout the season with some increasing others decreasing. There must be differences between Highbush and Rabbit eye varieties. These are considerations that we are currently researching and will pass the benefits on to our clients.

Water Analysis:

Irrigation water quality varies greatly and it is very important to know what you are working with. We frequently see high Bi-carbonate, high sodium and high boron waters. High iron waters are also an issue because pipes get clogged with rusty red iron sludge.

We at Bio Soil & Crop take pride in thinking about the many complex matters associated growing Blueberries and we are pleased to be of service to our clients.