St. Augustine Orchid Society

www.staugorchidsociety.org

Water Quality and Fertilizer in St. Johns County

by Sue Bottom, sbottom15@hotmail.com

Wells are the source of water in the St. Augustine area. The shallow wells are screened in shell and limestone strata so the water tends to be moderately to very alkaline. This will cause white lime deposits to precipitate onto leaves and plug leaf pores as well as to minimize the uptake of the needed and naturally occurring calcium and magnesium. You can compensate for this poor water quality by using a water soluble fertilizer that will tend to neutralize the natural alkalinity. Public water supplies are treated so have moderately low alkalinity. Organic matter (like fir bark, coconut husks or redwood bark) in the potting mix will buffer the pH and generate acidity. Once or twice a month thoroughly flush your pots to leach out residual salts. Here are some good fertilizers for our area that are readily available:

- *Private Shallow Wells.* For moderately to highly alkaline water, choose a fertilizer that has up to half of the available nitrogen in the ammoniacal form (the remainder being nitrate nitrogen, avoid high urea formulas). A balanced 20-20-20 fertilizer, available at retail outlets, will generate acidity and help neutralize some of the alkalinity in the root zone. Better yet are Peters Excel Multi Purpose 21-5-20 and Peters Professional 20-10-20 Peat Lite Special that will generate acidity. Supplemental magnesium may be required, apply Epsom salts at the rate of 1/4 teaspoon/gal with your regular fertilizer weekly or 1 tsp/gal monthly.

- *Public Water Supplies and Rainwater.* For pure to moderately alkaline water or if you grow in a highly organic mix like bark or coconut husk, you can choose a non acidity generating fertilizer. The Peters Excel 15-5-15 Cal Mag or 17-3-17 Peat Lite Neutral Cal Mag are low phosphorus MSU type fertilizers with calcium and magnesium. For those using rainwater, you may need supplemental magnesium, apply 1/8 tsp/gal with your regular fertilizer or 1 tsp/gal monthly.

1.0 Understanding Water Quality

1.1 Terminology

There are certain technical aspects of water quality that are important to orchid growers.

Table 1 - **Definition of Water Quality Terms**

Water Quality	Definition	Its Importance
pH	pH is a direct measurement of the balance between acidic hydrogen ions and basic hydroxide ions. The pH of a solution can range between 0 (very acidic) and 14 (very basic). At a pH of 7.0, the solution is said to be neutral. Irrigation waters should fall in the	When it comes to managing the pH of a substrate, the water alkalinity concentration has a much greater effect than does the water pH though water pH is still important for orchid growing. Even though it has little impact on the substrate, water pH

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Water Quality	Definition	Its Importance
	should be in the range of 6 to 7.5.	does affect the availability of nutrients and micronutrients, the solubility of fertilizers, and the efficacy of insecticides and fungicides.
Alkalinity	Alkalinity is the concentration of soluble compounds in the water that have the ability to neutralize acids. Alkalinity is related to pH, because water with high alkalinity has a high buffering capacity or capacity for neutralizing acids. The ions that have the greatest effect on alkalinity are bicarbonates and to a lesser extent carbonates. The concentration of all of the ions that makes up the alkalinity term are combined and reported as equivalents of calcium carbonate ($CaCO_3$). Alkalinity in the range of 30 to 150 is desirable.	Alkalinity is the most critical item to measure because it has a great effect on growing media pH. A certain amount of alkalinity is good, because it will buffer the solution from acidic influences such as sphagnum moss and fertilizer. Excessively high or low alkalinity levels will directly impact the availability of micronutrients in growing media. Low alkalinity may lead to depressed growing media pH and micronutrient toxicities, while high levels of alkalinity can increase the growing medium pH over time and lead to micronutrient deficiencies.
Soluble Salts	Soluble salts or electrical conductivity (EC) is a general measure of the total concentration of salts dissolved in the water. An irrigation source is best if EC levels are less than 0.75 mS/cm or mmhos/cm (equivalent to a total dissolved solids (TDS) content of 500), though levels up to 1.2 mS/cm (800 ppm TDS) may be acceptable.	Salt accumulation in the root zone can damage roots causing root tip burn. Regular monthly or bimonthly flushing of orchid pots will help dissolve and remove accumulated salts. Since the EC measurement does not identify which elements—helpful or harmful—are in the water, a complete nutrient analysis of water is necessary.
Calcium	Calcium is an essential element for plant growth that is often present in irrigation waters. It is required in large quantities by young growing tissues, strengthening stems and promoting strong overall plant growth.	Low levels will lead to poorly developed younger leaves or buds and other growing point disorders. Irrigation waters should have between 40 and 100 ppm Ca. When calcium levels are below these levels, it's necessary to supplement additional calcium for optimum results.
Magnesium	Magnesium is an essential element for plant growth that is often present in irrigation waters. It is an important component of chlorophyll, the green pigment that is responsible for photosynthesis. Maintain a good calcium-to-magnesium ratio in the	Irrigation waters should have a between 20 ppm and 50 ppm Mg. Pure waters will generally not have sufficient magnesium, and deficiencies may occur unless the nutritional program addresses the need. Symptoms of deficiency are generally

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	growing media (2:1 is recommended).	expressed as interveinal chlorosis of the older leaves first.
Sodium	Sodium is an undesirable ion found in well water if wells are screened in a salty shell layer or the aquifer is impacted by salt water intrusion.	Sodium is toxic to orchids at elevated levels. Ideally the irrigation water will contain less than 10 mg/l sodium. Levels above 50 mg/l are considered potentially harmful.
Sources: Understanding pH Management and Plant Nutrition Part 2: Water Quality, Bill Argo, Blackmore Company; Product Use Guide, Peters ABC Selection System; Irrigation Water Quality for Greenhouse Production, University of Tennessee, use TDS conversion factor of 670 (670 mg/l TDS = 1.0 mmhos/cm EC)		

1.2 Your Source of Water

Your water quality can vary greatly depending on its source.

- *Rainwater and Distilled Water* – are sources of very pure water having a very low alkalinity, categorized as Type 1 in the Peters system. There pure waters have virtually no buffering capacity so the addition of fertilizer can cause precipitous drops in pH and the water can end up with the acidity of vinegar. If you are using this type of pure water, you will need to use a non-acid generating fertilizer with calcium, magnesium and micronutrients because they are generally absent.

- *Public Water Supplies* – are sources of reasonably good quality water having a moderately low alkalinity, categorized as Type 2 in the Peters system, though the total dissolved solids are high as are the pH and sodium levels, which are over the 50 ppm recommended maximum level in some areas. Well water is treated to produce water of this quality in these service areas.

Table 2 - **Selected Water Quality Parameters in St. Johns County**						
Treatment Plant	pH (units)	Alkalinity (ppm)	Calcium (ppm)	Magnesium (ppm)	TDS (ppm)	Sodium (ppm)
Desirable Levels	*6 – 7.5*	*< 150*	*40 - 100*	*20 – 50*	*< 500*	*< 10*
Main Plant – CR 214	8.6	26	47	27	610	**84**
Northwest (World Golf Village)	7.4	135	67	40	500	30
Northeast (Nocatee)	7.9	137	67	36	686	**86**

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Desirable Levels	*6 – 7.5*	*< 150*	*40 - 100*	*20 – 50*	*< 500*	*< 10*
Fruit Cove	7.4	96	51	34	470	11
Bartram Oaks	7.8	107	104	46	780	23
SJC Ponte Vedra	7.9	120	53	31	430	22
Sawgrass Grid	7.3	141	58	33	448	21
St Augustine, St Aug Beach	8.8	36	46	25	410	33
Barry Stewart of the St. Johns County Utility Department and Patrick Timoney of the City of St. Augustine Water Department graciously supplied water quality data (August, 2014).						

- *Shallow Well Water* – in the St. Augustine area is high in alkalinity and total dissolved solids, categorized as Type 3 or 4 in the Peters system. The naturally occurring calcium and magnesium may not be easily available to your orchids because the water is too alkaline. Another major potential concern is the presence of sodium, which is toxic to your orchids at high concentrations. Do not use softened water on your orchids.

1.3 Root Zone pH

The pH of the substrate or potting medium rather than the pH of the irrigation water determines the availability of nutrients to your plant. The macronutrients and micronutrients tend to be available at their optimum level at a slightly acidic pH. The pH of the potting mix inside your pot is important because if it is too low you can have micronutrient toxicity and if it is too high nutrients can become unavailable to your plant.

1.3.1 Impact of Irrigation Water Alkalinity on Substrate pH

The most critical aspect of your water quality is the alkalinity, because this will largely determine the conditions that will prevail around the roots of your orchids. The water in the St. Augustine area tends to range from water type 2 (moderately low alkalinity) to water type 4 (very high alkalinity). If you notice a lot of white leaf spotting on your orchid leaves, it is likely that your water supply is highly alkaline.

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Table 3 - **Categorize Your Water Quality**		
Water Type	Relative Amount of Alkalinity	Alkalinity
1	Very Low	< 60 ppm
2	Moderately Low	60 – 150 pm
3	Moderately High	150 – 200 ppm
4	Very High	200 – 240+ ppm
Source: Product Use Guide, Peters ABC Selection System		

To categorize your water quality, it is best to obtain an analysis.

- You can get a very rough estimate of your water quality by taking a sample to a local pool supply company. Their results will give you a gross estimate of your water quality (you will have to adjust the value they give you for calcium, because they report it as calcium carbonate which must be converted to calcium by multiplying by 0.4).

- A much more accurate analysis can be obtained by sending a sample of your water to QAL in Panama City at a cost of about $32.50. Request the irrigation water suitability assay (nitrate nitrogen, ammonium nitrogen, phosphorus, potassium, calcium, magnesium, sodium, iron, manganese, boron, copper, zinc, molybdenum, aluminum, chloride, bicarbonate, carbonate, sulfate, electrical conductivity, and pH).

- Another alternative is sending your water sample off to J.R. Peters. At a cost of about $36 you can obtain a water analysis and then ask them to recommend a suitable fertilizer based on your actual water testing results (pH, soluble salts, total alkalinity, total nitrogen, nitrate nitrogen, ammonium nitrogen, phosphorus, potassium, calcium, magnesium, Sulfur, iron, manganese, copper, boron, zinc, molybdenum, aluminum, sodium, chlorides).

1.3.2 Impact of Fertilizer on Substrate pH

The first step in selecting the right water soluble fertilizer is knowing your water type.

- For low to moderately low alkalinity water types 1 and 2, an essentially neutral fertilizer formulation typical of a Cal Mag fertilizer is best to prevent an abrupt drop in the substrate pH.

- For moderately high to high alkalinity water types 3 and 4, an acidic fertilizer formulation helps neutralize the effect of the water alkalinity and makes the naturally occurring calcium and magnesium more available to the plant.

Fertilizers high in ammoniacal nitrogen (ammonium plus urea nitrogen) produce an acidic reaction in the substrate when absorbed by the plant, while nitrate based fertilizers

produce a basic reaction. There are several drawbacks to using fertilizer for alkalinity control. Fertilizers high in ammoniacal nitrogen may cause excessive growth and are not effective when the temperature of the substrate is less than 60°F. In addition, you lose flexibility because you can only choose commercial fertilizers based on ammonium content. For example, high ammonium fertilizers may lack calcium or other key nutrients.

1.3.3 Impact of Organic Matter in Potting Mixes on Substrate pH

The type and amount of organic matter present in potting mixes will also affect the pH of the substrate in the orchid pot. If your orchids are growing in an organic potting mix, you must consider the acidifying effect of organic matter when selecting a fertilizer. Sphagnum moss and peat moss tend to be quite acidic, followed by tree fern and redwood bark, to the moderately acidic bark and coconut husk. As this organic matter degrades over time, additional acidity is introduced to the root zone. The organic matter will increase the ability of your potting mix to hold water and nutrients so they will be available to the plant for a few days after you water. They will decompose over time and one of the byproducts of their decomposition is increased acidity.

If all your orchids are mounted or you grow in an inorganic potting mix that, then your fertilizer selection is based on your water quality. Inorganic matter like lava rock, hydroton, aliflor and charcoal has a large surface area that holds water for later uptake by the orchid. These materials are inert, so they have little buffering capacity, and will not degrade over time but will build up mineral deposits so it is important to flush the pot regularly.

- *High Alkalinity Water.* For those with alkaline water, the increase in acidity from the degradation of the organic matter is good as long as the pH does not drop too much below 5. Of course, the preferred acid generating fertilizer for high alkalinity water is also causing a drop in root zone pH.

- *Low Alkalinity Water* – With pure water, such as rainwater, or water low in alkalinity, the substrate exerts a greater influence on root zone pH for a longer period of time. For those with low alkalinity water, the degradation of organic matter cause relatively rapid drops in root zone pH if the water has little acid buffering capacity, though this would be partially mediated by the use of slightly basic Cal Mag fertilizer preferred for low alkalinity water or exacerbated by the use of an acid generating fertilizer.

- *Sphagnum Moss* – is a very water retentive medium that is very acidic, with an initial pH of around 4, so much so that bacteria and fungi cannot survive in it. It also breaks down fairly rapidly, with a life of one to three years depending on the quality of the moss (AAA, now referred to as Supreme, and AAAAA, now referred to as Premier Strand, are the best, don't use a grade lesser than the more difficult to find Premier, the most available Classic grade is best used for top dressing). Some growers swear by

sphagnum and others cannot successfully grow in sphagnum. Use a basic Cal Mag fertilizer rather than acid generating fertilizer.

1.4 Fertilizer Selection

The following fertilizers are suitable for our local water quality based on the data contained herein. Have a detailed analysis of your water will confirm the actual quality of your water.

- *Rainwater or Deep Wells* – Use a Cal Mag fertilizer, depending on the formula you may use Epsom salts for extra magnesium
- *Public Water Supplies* – Use a Cal Mag fertilizer or Peters Professional 15-5-25 Peat Lite Flowering Crop Special.
- *Private Shallow Wells* – Use an acid generating fertilizer like 21-5-20, 20-10-20 or 20-20-20 with supplemental Epsom salts.

Peters has an online fertilizer selection tool to help you choose your fertilizer. You can also download a selection guide with lots of detailed information about their fertilizers. Different fertilizers, their suitability for a given water type and the potential basicity and acidity of the fertilizer are summarized in the following table.

Table 4 - **Peters Fertilizers Ranked in Order of Increasing Acidic Fertilizer Reaction**

Fertilizer Name	**Formula** N-P-K % nitrate nitrogen Ca, Mg micronutrients	**Description**	**Fertilizer Reaction** Pounds of acidity or basicity per ton of fertilizer
Peters Excel 13-2-13 Plug and Bedding Plant Special[1]	13-2-13 93% nitrate N 6 Ca, 3 Mg micronutrients	All-purpose formulation combines high nitrate and low phosphate with extra calcium and magnesium. Most effective for irrigation water having an alkalinity below 150 ppm.	335 Basicity
Peters Excel 15-5-15 Cal Mag Special[1]	15-5-15 79% nitrate N 5 Ca, 2 Mg micronutrients	All-purpose formulation combines high nitrate and low phosphate with extra calcium and magnesium. Ideal for irrigation water having an alkalinity of 60 to 150 ppm.	131 Basicity
Peters Excel 17-3-17 Peat Lite Neutral Cal Mag[1]	17-3-17 76% nitrate N 4 Ca, 1.5 Mg micronutrients	All-purpose formulation produces a nearly neutral reaction to help maintain steady pH in growing media. Ideal for water having an alkalinity below 150 ppm.	27 Basicity

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Fertilizer Name	Formula N-P-K % nitrate nitrogen Ca, Mg micronutrients	Description	Fertilizer Reaction Pounds of acidity or basicity per ton of fertilizer
Peters Professional 15-5-25 Peat Lite Flowering Crop Special[2]	15-5-25 71% nitrate N 0 Ca, 2.5 Mg micronutrients	High-nitrate, low-phosphate formula with extra magnesium. Effective for all water types, stand-alone product formulation for water having alkalinity above 150 ppm.	48 Acidity
Peters Excel Multi Purpose 21-5-20[2,3]	21-5-20 60% nitrate N 0 Ca, 0 Mg micronutrients	Moderately acidic formulation serves as an all-purpose fertilizer, appropriate for water having an alkalinity over 60 ppm.	300 Acidity
Peters Professional 18-8-17 Peat Lite High Mag Special[2,4]	18-8-17 59% nitrate N 0 Ca, 2.5 Mg micronutrients	Extra magnesium to maintain deep green foliage. Effective for all water types, stand-alone product formulation for water having alkalinity above 150 ppm.	381 Acidity
Peters Professional 20-10-20 Peat Lite Special[2,3]	20-10-20 60% nitrate - 0.15 Mg micronutrients	Acidifying action corrects an overload of excessive pH in growing media, effective for all water types.	415 Acidity
Peters Professional 20-20-20 Ag & Landscape Special[2,3]	20-20-20 28% nitrate N 0 Ca, 0 Mg micronutrients	Acidifying action can help combat excessively high pH in growing media.	570 Acidity

[1]Fertilizer for those with low alkalinity water (alkalinity below 150 ppm)
[2]Fertilizer for those with high alkalinity water (alkalinity above 150 ppm).
[3]May have to supplement with Epsom salts or Magnitrate to provide enough of the necessary magnesium.
[4]Not available from BWI in Apopka

Source: *Peters Complete Product Use Guide*, available online at http://everris.us.com/peters-complete-product-use-guide-usa

Certain supplements will alter your root zone pH. The often used dolomitic lime used to increase available calcium and magnesium will result in an increase of pH. Gypsum (calcium sulfate) is an alternative calcium source that will provide calcium without increasing the root zone pH.

1.5 Check the Root Zone pH to Verify Your Fertilizer Regime

To test your root zone pH, place your orchid pot in a plastic bag and add distilled water until 3/4 of the pot is full of water. Let the pot stand in the water for half an hour, then remove the bag, pour it through a coffee filter and analyze a sample of this filtered water for pH, such as with colorimetric test strips or drops available from hydroponics stores. If

the pH is in the desired 6 to range, your fertilizer regiment is working. If it is continue your fertilizer regimen.

2.0 Mineral Nutrition

A complete fertilizer program provides macronutrients needed in large quantities and the micronutrients needed in small quantities. The nutrient content of the irrigation water can supply a large percentage of nutrients, especially calcium and magnesium, to the plants. The nutrients required for orchids are listed in the following table.

Table 5 - **Mineral Nutrition for Orchids**

	Continuous Feed (ppm) Fertilize at Least Weekly	Periodic Feed (ppm) Fertilize Less than Weekly
Macronutrients		
Nitrogen, N	60 - 100	100 - 200
Phosphorus, P	10 - 20	20 - 40
Potassium, K	60 - 100	100 – 200
Calcium, Ca	40 - 80	80 - 160
Magnesium, Mg	20 - 40	40 – 80
Sulfur, S	15 - 25	25 - 50
Micronutrients		
Boron, B	trace	< 0.8
Iron, Fe	>0.5	2
Manganese, Mn	> 0.2	2
Zinc, Zn	1	2
Copper, Cu	trace	< 0.2
Molybdenum, Mo	trace	<0.05

Source: adapted from Bob and Lynn Wellenstein, AnTec Laboratory

If you match the acidifying effect of your water soluble fertilizer to the alkalinity of your irrigation water and are using a balanced low urea commercial fertilizer at a rate of 50 to 100 ppm nitrogen, your likely only serious mineral nutritional concerns are calcium and magnesium. Orchids grown in bark probably require twice that nitrogen level to compensate for the nitrogen consumed in bark decomposition.

2.1 Fertilization Rates

Using high fertilizer application rates will cause faster growth but it is possible the plant will be more susceptible to fungal and bacterial diseases.

- *Choose Target Nitrogen Level* - For a mixed collection, 70 ppm N should work well for weekly feeding. To calculate your fertilizer application rate, enter your target N concentration and the percent N from the fertilizer label and enter it into this calculator from the First Rays website.

- *Flush Pots Regularly* - Flush your pots religiously, once or twice a month, with your raw water. Water the plant until water runs out the bottom of the pot and then water some more. This will dissolve the salts. Wait 15 to 60 minutes and then repeat this flushing procedure, this will flush the dissolved salts out of your pot.

- *Calcium and Magnesium* – The Cal Mag fertilizer you use for low alkalinity water contains calcium and magnesium. The acid generating fertilizer you use with our high alkalinity well water doesn't contain calcium or magnesium, but the drop it causes in root zone pH makes the naturally occurring calcium more available to your plants. This high alkalinity water is deficient in magnesium , so add ¼ tsp/gal Epsom salts to your fertilizer. During the summer growing season, consider adding supplemental calcium nitrate (available at the local feed store) to your plants. Apply ½ teaspoon/gallon monthly with your fresh water flush, do not apply with your fertilizer or magnesium supplements. Another alternative is to incorporate dolomitic lime into the potting mix or top dress pots with dolomitic lime, particularly for cymbidiums and paphiopedilums, although you may want to check your root zone pH to make sure it does not become too elevated..

2.2 Nutrient Deficiencies

Table 5 addresses the signs of deficiency or an excess of nutrients that can be used to diagnose any deficiency in your fertilizer program. An element's translocatability in the plant is important in diagnosing deficiencies. If it is translocatable, the plant can remove it from tissue in one area and transport it for use in another, so symptoms of deficiency typically occur in the more expendable older tissue. Conversely, if the element is not translocatable, then the deficiency will show more in the new growing area of the plant. If you are fertilizing, the most likely cause of a mineral deficiency is the loss of the roots of the plant leaving the plant unable to absorb the needed nutrient levels.

Table 6 - **Signs of Deficiency and Excess of Mineral Nutrients**

Mineral Elements	Primary Functions in Plant	Signs of Deficiency	Trans-locatable?	Signs of Excess
Nitrogen, N	Growth of green (leaf and stem) portions of plant	Reduced growth, vigor, chlorosis of older leaves first, premature leaf drop	Yes	Soft growth, spindly growth, leaf curl, reduced flowering, symptoms of potassium deficiency

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Table 6 - **Signs of Deficiency and Excess of Mineral Nutrients**

Mineral Elements	Primary Functions in Plant	Signs of Deficiency	Trans-locatable?	Signs of Excess
Phosphorus, P	Essential for root growth, flowering and seed production	Older leaves affected first, an increase in anthocyanin pigment and a dark blue green coloration, sometimes with necrotic areas and stunting	Yes	Symptoms of nitrogen, zinc and iron deficiencies
Potassium, K	Root growth, sugar and starch production, cell membrane integrity	Dwarfing, chlorosis of older leaves first, leaf curling	Yes	Symptoms of nitrogen, magnesium, calcium, iron, zinc, copper and manganese deficiencies
Calcium, Ca	Cell wall formation, cell division, enzyme catalyst, neutralization of toxic metabolites	Poor growth, deformed or chlorotic newer leaves, blackened areas at leaf ends and new growths with a leading yellow edge, stunted, shortened roots, dead root tips	Slightly	Symptoms of magnesium deficiency
Magnesium, Mg	Chlorophyll and protein production, carbohydrate metabolism, enzyme activation	Interveinal and marginal chlorosis starting in the older leaves, increase in appearance of anthocyanin in leaves, necrotic spotting	Yes	Symptoms of calcium deficiency
Sulfur, S	Protein formation, photosynthesis and nitrogen metabolism	Root stunting, general chlorosis starting with younger leaves	No	
Boron, B	Sugar transport, DNA synthesis	Death of meristematic tissue, root stunting, no flower formation	No	Interveinal leaf necrosis
Iron, Fe	Component of cytochromes and ferrodoxin, synthesis of chlorophyll	Interveinal chlorosis of newer leaves	No	

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Table 6 - **Signs of Deficiency and Excess of Mineral Nutrients**				
Mineral Elements	Primary Functions in Plant	Signs of Deficiency	Trans-locatable?	Signs of Excess
Manganese, Mn	Enzyme activation in respiration and nitrogen metabolism	Interveinal chlorotic and necrotic spotting	No	Stunting, necrotic spotting of leaves
Zinc, Zn	Trytophan synthesis, electron carrier protein in chloroplast	Smaller, distorted leaves, stunting, interveinal chlorosis of older leaves, white necrotic spotting, resetting	No	Symptoms of magnesium and iron deficiencies
Copper, Cu	Enzyme component, electron carrier protein in chloroplast	Stunted misshapen growth	No	Symptoms of magnesium and iron deficiencies
Molybdenum, Mo	Nitrogen and potassium metabolism	Chlorotic interveinal mottling, marginal necrosis, folding of the leaf, no flower formation	Slightly	
Source: Bob and Lynn Wellenstein, AnTec Laboratory				

3.0 Citations and Information Sources

Fertilizer ppm Calculators, Ray Barkalow, First Rays, available online at http://firstrays.com/free-information/feeding-and-watering/measurement-handling-application-of-fertilizers/nitrogen-management-calculator/

Mineral Nutrition for Slipper Orchid Growers, Bob and Lynn Wellenstein, AnTec Laboratory, available online at http://www.ladyslipper.com/minnut.htm

Peters Complete Product Use Guide, available online at http://everris.us.com/peters-complete-product-use-guide-usa

Peters ABC Selection System, available online at http://everris.us.com/plant-nutrition/water-soluble-fertilizers

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Part 2 - Water Quality, 2004, Vol. 13(1)
Part 3 - Fertilizers, 2004, Vol. 13(2)
Part 4 - Substrates, 2004, Vol. 13(3)
Part 5 - Choosing the Best Fertilizers, 2004, Vol. 13(4)

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