Understanding pH in Hydroponics – Part No.1

When water reacts with itself to create the H3O(+)(hydroxyl) and OH(-) (hydroxide) species, one of the most fundamental and important characteristics of aqueous solutions is generated. The reactivity of a solution and its interaction with living organisms is determined in a great extent by the concentration of these two species, a variable usually measured as pH which is nothing but the negative value of the logarithm of the concentration of the H3O(+) ion. In hydroponic culture – where our plants are in great contact with aqueous solutions – the understanding of the role of the H3O(+) and OH(-) ions and their measurement as pH becomes very important if an in-depth understanding of what is going on wants to be attained. On today's post I will attempt to guide you into this micro world of pH and how and why pH changes within a hydroponic crop. Tomorrow -on Part No.2 – I will try to explain to you how plants adapt to pH changes and what a pH change actually means for a living organism.

What determines pH ? This variable is inversely proportional to the concentration of H3O(+) ions and directly proportional to OH(-) ions, the more hydroxil ions you have the more acidic your solution will be (the lower the pH) while more hydroxide ions will increase your pH and give you a higher pH reading. It is important to understand here that hydroxyl and hydroxide ions determine each other's concentration. Since water's self-reaction equilibria must be maintained, the sum of pH and pOH must always be equal to 14 (a neat consequence of chemical equilibrium theory). When the concentration of hydroxyl and hydroxide ions is equal, pH and pOH contribute equally to the solution and they are therefore both 7, reason why the pH of a neutral solution has this value.

Now that we know a little bit about pH we can understand better what happens when plants interact with a nutrient solution. When a plant is put within a given solution it wants to absorb the nutrients it needs to grow. These nutrients are avilable as ions that have a given charge. For example, nitrogen is absorbed as the nitrate ion (NO3(-)) while potassium is absorbed as the K(+) ion. When a plant takes potassium in, it depletes the solution of a positive charge. Since the solution must remain neutral the plant gives the solution an H3O(+) ion to compensate. The plant has therefore decreased the pH of the solution by absorbing a potassium ion. When nitrate is absorbed – an ion with a negative charge- the plant does the opposite and exchanges the nitrate for an OH(-), the pH of the solution is increased.

If plants absorbed nutrients in a perfectly symmetrical fashion, they would not increase or decrease pH as overall charge changes would be compensated. However – as no one is perfect- plants absorb nutrients at different rates and they therefore create a “pull” towards a certain pH region. If a plant absorbs nitrate heavily it will start to contribute far more OH(-) than H3O(+) ions into the solution and the result will be a net increase in pH. Depending on the composition of the nutrients and the overall growth stage of the plant, different net movements in pH can be achieved by the plant.

The most influential factor in the changes of pH within a solution is generally the composition of the nitrogen component of the solution. When plants absorb ammonium ions NH4(+) they tend to decrease pH while nitrate – as mentioned above – tends to increase pH when absorbed. If you contribute a percentage of the nitrogen in your solution as ammonia the net effect will be a beneficial “absorption pH buffer” since plants will take nitrogen in both forms, effectively delaying the onset of important pH variations. Of course, the ratio of nutrients also performs a vital role since plants’ nutrient absorption mechanism are largely non-specific and they are greatly influenced by the different concentrations of nutrients within the solutions. Having a nutrient solution designed to provide an adequate balance will be vital in helping you control pH fluctuations.

On part two of this “understanding pH in Hydroponics” post I will talk about the range of pH plants can live in, how they adapt to changes in pH and other interesting aspects that will help you better understand the role and true importance of pH within a hydroponic crop. I hope that today you have acquired a rough idea of what pH represents, the nature of pH changes and some basic things that can be done to improve the pH balance within your hydroponic culture.

Growing a Hydroponic Garden Without a pH or EC meter

So you have decided you want to start a hydroponic garden but you do not want to use a pH or an EC meter. It is fairly common for people to feel this way when they are starting their own hydroponic gardening due to several reasons. Maybe you are not very familiar with the technical side of hydroponics, you don’t want to get into all that stuff in the beggining or perhaps pH/EC meters are terribly hard to get or expensive where you live. Does this mean that without a pH and EC meter you won’t be able to run a successful hydroponic venture ? No. On today’s post I am going to talk to you about how you can grow hydroponic crops without a pH or EC meter and yet get good results, sometimes even better than people using all those technical gizmos :o).
As a chemist I think like a scientist and part of this way of thinking is the controlling of variables. I like to control pH and EC because I feel that this allows me to have a record of what is happening within my nutrient solution, without these measurements I would be “blind”, so to speak. However when I

was beginning my major I started my first hydroponic ventures with absolutely no control over pH or EC. I didn't do this because the cost of an EC/pH meter where I lived was prohibitive so I said, "what the hell" and went for it. I have to say that I got some very satisfying tomato crops after having some significant failures due to both rookie mistakes and disease. I managed to get full, 2 meter high tomato plants filled with delicious vibrant tomatoes and this happened without ever checking my pH or EC.

How did I manage to do this ? After time went by and I got an EC/pH meter, I started to monitor how my crop evolved with time to know what I should or should not do to improve my corp's yields. I found out that the pH of my crop increased steadily – and sometimes came near 8 – before I usually changed my nutrient solution. The EC oscillated widely but my reposition of the initial "level" of solution with water was enough to keep the EC at a good level. So if you want to be successful with hydroponic crops, it is not absolutely vital for you to have a pH or an EC meter, you just need to follow some simple guidelines to have a wonderful hydroponic crop.

1. Have one gallon of nutrient solution per plant. Having this volume of solution in your reservoir per plants allows you to have enough nutrients so that each plant will take a significant amount of time to absorb them. Having less solution is troublesome since your EC will change wildly and your nutrient solution changes will have to be more frequent. A one gallon per plant rule of thumb seems to be the best choice.

2. Add fresh water to recover the initial level of your solution . This is one of the easiest things to do. By adding fresh water -without any nutrients- to top off your reservoir to its initial level you will keep the EC near its initial value for the whole time. This simple technique ensures that your EC remains within rational levels and your plants stress-free.

3. Change your solution every 4 weeks. After 4 weeks, in a hydroponics system where there is one gallon per plant and the solution is continuously topped off (at least once a day) you will find that your plants have used about 40% of the nutrients at most (this is what I got from full production tomato plants and an atomic emission analysis of the nutrient solution). This means that your solution is now deprived of nutrients and it is time to use the solution to water your soil-garden and prepare everything again.

With this simple guidelines, anyone will be able to grow a hydroponic garden without using a pH or an EC meter. Of course, in the beginning you may find some problems while you find the adequate level of nutrients your plants need (if you do not prepare them yourself) but after a few trial and error runs you will be able to grow full hydroponics gardens without having to constantly monitor either pH or EC. Certainly, better results are achievable when you are monitoring these variables but it is possible to grow a beautiful hydroponics crop without the slightest monitoring of these aspects of a hydroponic nutrient solutions. People usually underestimate the ability of plants to adapt to changing conditions, something that they are able to do beautifully if you only follow the above advice. **Do you have any advice or suggestions to help people grow without an EC or pH meter ? Feel free to leave a comment :o)**

Is OceanGrown Fertilizer a Scam ? A Scientist's Point of

View

In recent days I was contacted by a person who wanted to start selling the OceanGrow fertilizer who asked me to be the head of a research team to do scientific tests to evaluate if there is actually any value behind the OceanGrown fertilizer. After going through its webpage and doing and in-depth review of scientific literature on the subject I have acquired quite a lot of information about this fertilizer and its real potential as an organic solution and replacement for traditional fertilizers. On today's post I want to discuss this fertilizer, which is supposed to be used on either soil or hydroponics, and give you my opinion as a scientist and what the currently available scientific evidence tells us about the effectiveness of this and similar products.
The OceanGrown fertilizer is nothing more than sea water which has been concentrated – probably using reverse osmosis – to give us a fertilizer that is supposed to replenish the minerals lost in soil and provide plants with 90 elements for their adequate and healthy growth. The website has an overall pseudo scientific tone with absolutely no reliable scientific evidence shown and basing all conclusion on "facts" that have not been scientifically proved. For example, the website says that elements in sea water are in "ideal concentrations" when this has no scientific basis, no one has proved that certain nutrient concentrations are ideal and no study has actually been conducted to see if the concentrations of micro nutrients on sea water are ideal for plant growth.
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Besides this, the people at OceanGrown assume that having all elements is "good" when actually even small amounts of mercury, lead, cadmium and other heavy metals can cause chronic effects when eaten continuously. They also show evidence that the elements are absorbed by the plants fed with their product something which is absolutely obvious given the fact that ionic species are absorbed by plants since their absorption mechanisms are not extremely controlled. Does the fact that a plant absorb aluminium or gold prove that the element is essential ? No, plants absorb ionic species without

too much selectivity and when you feed a plant with a solution containing non-essential nutrients the plant is bound to absorb some. This effect is widely studied in science to remove heavy metal contamination and other ionic species using plants. There is no scientific evidence that points out that any elements besides C, H, O, N, P, K, Mg, Ca, Fe, Zn, Mn, Cl, Mo, B, S and Cu are essential to plant life or needed for the adequate and healthy development of plants.
The “essays” carried out to test this fertilizer’s efficiency also lack any use of the scientific method and fail to discard very plausible causes of this fertilizer’s sometimes positive effects. For example, increases in conductivity have been found to improve certain crops in hydroponic culture so the effect of this fertilizer might only be of ionic strength increasing which might help certain crops achieve better results. It is also possible that some micro nutrients – which are depleted in soil – might be added by this fertilizer but in the long term the excessive amount of sodium and chloride ions contained in sea water is bound to cause problems. The evidence that increased sodium concentrations in hydroponic crops causes damage to plants is a well established fact in the scientific community.

The people at OceanGrown seem to be trying to sell a fertilizer with extremely limited and lack of adequately confirmed evidence based on a series of pseudo scientific facts that are not adequately backed up by our current understanding of how plants work. This fertilizer might be able to work to some extent but the reasons why it does or if it causes any long term problems and damage to soil needs to be addressed to confirm the viability of this solution. Right now there is not even one single study published on a peer-reviewed scientific journal that talks about the effectiveness of OceanGrown or true scientific essays done with this solution. It seems evident to me that similar effects as the ones shown by this fertilizer might be achieved by a simple application of an adequately formulated micro-nutrient mix and that positive effects from all the trace elements found in sea water might be limited or undetectable at best.

In conclusion, I think that the OceanGrown fertilizer is a big business based on selling sea water that is currently based in pseudo scientific results. There is no evidence that plants need or benefit from 90 different elements and there is also no evidence that shows that this fertilizer has no long term ill effects due to the excessive sodium enrichment of soil. If this people were truly serious about proving that their fertilizer works in a unique way based on all of its trace elements they would have made adequate scientific trials years ago with reputable scientists from world renowned universities. My advice if you are thinking about using this solution would be to use what we know and have determined works for plants. The application of adequately formulated micro nutrient blends and full fertilizers is a much better solution than a pseudo scientific mess with no adequate scientific evidence of unique results.

Of course I am a scientist and as soon as there is a peer reviewed publication on a well-respected journal done by an unbiased researcher I will be the first to reexamine my conclusions and use this fertilizer. Meanwhile OceanGrow remains unproved and their claims or at least their explanations, remain pseudo scientific.

Fruit Quality and High EC values in Tomatoes

You may remember an article I wrote last year about the effect of salt concentration in tomatoes and how several different studies have been done about this matter. On that article I talked about a paper released in 2007 showing that tomatoes raised at an electrical conductivity value of 4.5 dS/m had the best tasting and fruit quality. However, this study was not conclusive in the sense that quality parameters used on the plants where not extensive and adequately analyzed. On today's post I want to talk to you about a previous study done in 2006 which does include fruit quality parameters and a clear explanation about which conductivity levels give you the best tomatoes and why this is the case.

The relantionship between high conductivity and high fruit quality clearly depends on how you evaluate fruit quality. In general, the nutritional quality of a fruit is measured by the concentration of important nutrients within it. In the case of tomatoes, important nutrients such as lycopene, vitamin C, carotenoids and phenolics determine most of the tomato's nutritional value. However, fruit quality – from a market perspective – relates to size, shape, uniformity and firmness and market duration.

On a study published on the Journal of Agricultural and Food Chemistry in 2006, Woitke *et al* discussed the effect of electrical conductivity on the yield and quality of tomato crops. Their conclusions after analyzing the concentration of several nutrients at different salinity levels was clear : tomato crops which are raised at higher EC levels have lower overall yield but the concentration of nutrients (vitamin C, lycopene and beta-carotene) was increased by as much as 38% on high conductivity treatments (again at about 4-4.5 dS/m). They also found a nutrient-quality increase as the antioxidative capacity of the phenols and carotenoids increased on the plants with high nutrient treatments.

Another very important fact is that not only nutritional value was increased but total dissolved solids and organic acids – which contribute significantly to the fruit's flavor – also increased significantly. Overall the study concludes that all quality related parameters increased with the increase in salinity pointing out clearly that raising tomatoes at high salinity levels is an excellent way to increase fruit quality.

The reduction of yield can be compensated for by the higher inner quality of the fruit allowing it to compete more effectively with other higher-yielding yet lower quality productions within the market.

So next time you want to increase the taste and nutritional qualities of your tomatoes just raise your EC levels so that your fruits accumulate the higher levels of nutrients and flavor producing substances that reside within every small tomato. Certainly your tomatos will be the envy of all other growers with their higher nutrient and flavor levels and increased antioxidative capacity.

The Best Outdoor Hydroponic System. A Simple Way to Grow Large Amounts of Food

I have always seen that there is not a lot of information regarding outdoor hydroponics and the building of scalable and cheap systems that may provide large amounts of food without the complexity, trouble and expense of building a greenhouse. For the past several years I have been puzzled by this issue and I have challenged myself to build an outside hydroponics system that is able to deal with environmental conditions successfuly, providing adequate conditions for plant growth without significant expenses and without the need for any protective enclosure. Finally, I came up with a system which – I believe – has a lot of promise for the above, giving us the opportunity to build an outdoor hydroponic system which has a low cost and a very high productivity potential. On today's post I will be talking about this system and how it can be easily built with less than 1K USD for each 100 square meters. How do you build a scalable system that can be used on the outdoors with minimal problems due to uncontrolled environmental conditions ? The easiest thing I could think of was a simple continuous flow system which used the ground itself as a place to put the plants. This system uses no NFT channels, no large amounts of PVC pipes and absolutely no complex engineering. The system – shown on the drawing below – is simply a channel which is dug on the ground of about 2 meters wide by 25 cm deep. The nutrient reservoir can be a tank burried in the ground or a reservoir made from bricks and tiles out of another hole dug on the ground depending on the actual volume needs of the crop. The hydroponic system uses a PVC line connected to a pump to irrigate the system at the top and a small decline in the slope of the channel allows the solution to return to the tank through an underground pipe shown in dark blue. The channel is filled with a nutrient media that has adequate drainage and the nutrient solution is fed continuously through the irrigation system. Of course, when the channel is dug on the ground the soil has to be covered with a polyethylene sheet to prevent the solution to drain into the soil.

This system allows you to grow a wide variety of crops, from tomatoes to lettuce heads. The system can be used to grow plants of various sizes and nutritional needs since the media and continuous flow irrigation provides great oxygenation as well as a cheap alternative to more complex systems such as NFT or PVC pipe systems. The system is also absolutely scalable, it can be built from a few square meters to a full plot size commercial cultivation facility without significantly changing the principle of operation. Since the surface area of the system is also large, and all nutrient solution is returned to a central reservoir, rain volume can be accurately determined and nutrients can be added or changed to make up for this effect of external environmental conditions.

The image shown below shows you how the system can be expanded to a full plot system without any modification of the fundamental working principle. The only things that need to be bought to start this system are a tank, a shovel, a polyethylene sheet as large as the channel requires, PVC pipes for the irrigation system and returns pipes, media, nutrients and seed. Since there is no greenhouse, no gutters, no polymer channels and no expensive irrigation equipment, the system is very simple and effective at growing plants at a large or small scale under outdoor conditions. It is also perfect for people who want to start a small hydroponic business and then expand it as they want to increase their production, since adding channels is easy and requires almost no changes (besides perhaps having larger pumps and increasing reservoir size once this is required).

In the end I believe that this system summarizes everything that I wanted to achieve with an outdoor hydroponic system. It is able to control and measure the effect and added volume of rain, allows the growth of a large variety of plants and provides us with a cheap and scalable solution to small and large scale commercial growing. Definitely there will be some problems that will probably have to be solved once larger applications start to develop but certainly I can say right now that this idea seems to be the largest, cheapest and most scalable solution for outdoor hydroponic growing available online :o).

Crazy pH Swings – How Media

and Bacteria Affect pH in Hydroponics

I usually get an email from time to time from someone who is experiencing wild pH swings in their hydroponic reservoirs. Growers usually tell me that their pH was around 6.2 one day and then 8.0 by the next morning or some similar story. This situation becomes a little bit frustrating as the grower does a huge effort to keep the solution at a certain pH level only to realize that after a certain time the pH of the solution simply starts to swing wildly between very odd values. In order to help new and experienced growers better understand the nature of these swings, what they mean, and how they can be eliminated for good I decided to write this small article on hydroponic pH swings and how variables different to plant feeding affect pH levels.

Let’s suppose you got home from work, prepared a new batch of nutrient solution and set your pH level at a very comfortable level of 5.7. By the next day, when you wake up in the morning to check your plants you find that the pH of your solution is 7.5. You start to argue with your pH meter, recalibrate, readjust your solution and leave for work. When you come back – to your surprise – your pH level is now around 7.3. What ? – you ask yourself – What could be wrong if you set the pH to 5.7 again and it again went up to 7.3 ?

The answer to these wild pH swings comes from an understanding of the chemistry behind everything within your hydroponic system. Generally these swings towards high pH values are caused by media which has surface-active basic sites which act like “buffers” and readjust the pH of your nutrient solution to their own “preset” pH level. This is very much like the mechanism used by soils to naturally control pH, only that this time the minerals are playing against you. Substrates that have been made at high temperatures which have basic potential – such as rockwool – show this kind of behavior.

Other media such as river bed gravel also show strong pH buffering effects due to their natural mineral composition.

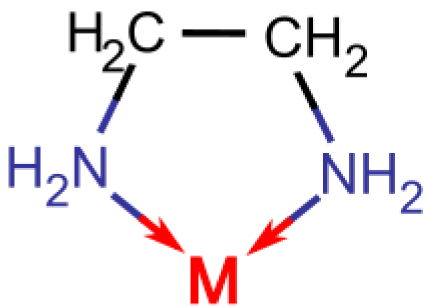
How do you end this problem ? The easiest way to end this problem is to pretreat your media before starting your crop. Place your media in a bucket and then add 1 liter of vinegar for every gallon of water. The media will attempt to neutralize the acetic acid and in doing so it will lose the proton capturing ability of its surface basic sites. Using a weak acid like acetic acid is better than using a strong acid – like nitric acid – because this ensures that residual acids within the media won't lead to other extreme pH fluctuations. After the media is soaked in the vinegar solution measure the pH, wait a day and measure it again. If there is no difference between both readings then you can now wash and use the media – if there is – then you need to wait another day and remeasure.

Now basic media is not the only problem around. There are also wild swings to acid values which are usually a consequence of bacterial growth or dying organic matter. When organisms die or when they are being decomposed by bacteria organic acids – which lower pH – are released into your nutrient solution. Wild swings into the 3.5-4.5 region usually mean that the problem is not media but related to root disease. You should do a hydrogen peroxide treatment (check my articles on peroxide for more on this) and wait to see if pH levels stabilize after a while. In extreme cases, physical removal of dead root material may be necessary to correct the problem.

Last but not least, the problem can also be related with plant feeding from a very scarse volume of solution. If you are handling less than 1 gallon per plant of solution in your reservoir then it is likely that plants themselves – through the absorption of nutrients – are causing the swings. This is easily fixed by placing a larger reservoir and ensuring that you are always recirculating at least 1 gallon per plant of nutrient solution. Hopefully with the above guide you will be able to better understand “wild” pH swings and take corrective action whenver you see this behavior happening within your hydroponic crop.

Preparing your Own Chelates – Improving Your Hydroponic Nutrients

If you have already read my free ebook for preparing hydroponic solutions and you have already seen many commercial and other standard formulations you may be asking yourself if you will have problems with iron due to the unavailability of any chelating agents. The truth is that I have used formulations without any chelating agents several times and I haven’t had any problems when they are prepared by the ebook. However many of you may be interested in the addition of chelating agents and you may wondering how you may modify the spreadsheet or what you should add in order to generate the adequate chelates. On this post I want to explain a little bit how you can add chelating agents to your reservoir to chelate the salts mentioned on my ebook and how this can easily generate all the chelated metal complexes you need to avoid any solubility problems.



Simple metal chelate model representation

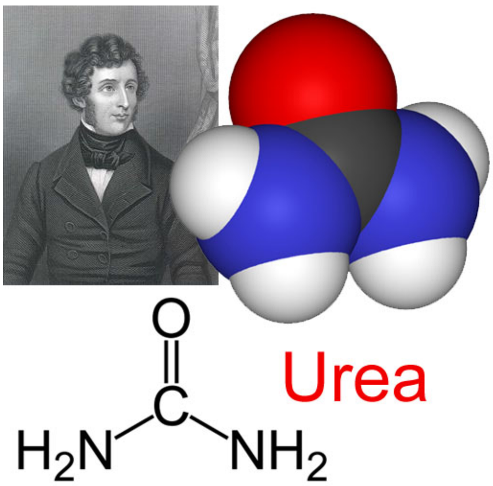
What is exactly a chelate and what are they good for ? A chelate is simply an organic molecule that “wraps” itself around a metal ion and prevents its precipitation, increasing its solubility. Chelates also diminish the amount of available metal ions to plants and therefore they slowly release the quantities of micro nutrients available for plant growth. There are many available pre-made chelates on the market such as Fe-EDTA. However, the cheapest way to generate chelates once you already have a standarized formulation based on simple inorganic salts is to add a chelating agent.

The most common of these agents is called Ethylendiamintetraacetic Acid (EDTA), a tetraprotic acid which is able to chelate most metals with a particularly high afinity for Fe. However, when you add only chelated iron, the fact that other metals start to compete makes the iron complex destabilize and the chelate is eventually destroyed. However, when we add the chelating agent we can make sure that we add enough to “wrap” Fe and other metals in such a way that the stability of the iron complex is guaranteed.

When we add the chelating agent we do not add EDTA (the acidic form) but we add it as a salt of another element, usually K-EDTA. Once this is added to the solution the EDTA quickly gets rid of K and goes for another metal – such as Fe – for which it has a much higher affinity. The chelating agent quickly forms complexes with all the metals it loves and you end up with a solution that is highly stable and not prone to any micro nutrient related precipitation. How much do you need to add ? Depends on your formulation. The spreadsheet download with the ebook shows the amount of chelating agent (K-EDTA) you need to add to the END solution after all micro nutrient concentrated solution additions have been done (this amount fully complexes Fe, Mn, Zn and Cu).

Urea in Hydroponics – Positive or Negative ?

When we supply nitrogen in our hydroponic solutions there are always a several ways in which we can fulfill our plants' needs for this nutrient. The traditional way is to supply nitrogen solely as nitrate (NO3-) salts, something which is well proven to give good results, high yield crops and better than soil growth. However it is always good to ask if a combination or the use of additional nitrogen sources may improve the outcome of our hydroponic experience. Particularly since plants in soil absorb nitrogen as nitrate and ammonia it becomes worth asking if a slow releasing source of ammonia- such as urea – would improve the yields of our hydroponic system. On this post I will write a little bit about the use of urea in hydroponics and the scientific evidence that there is to support or reject its use.



Model of a urea molecule

Urea is an organic molecule which slowly decomposes in water to yield ammonia and carbon dioxide. If the media is slightly acidic, the ammonia released will get protonated to form ammonium, a form of nitrogen which can be readily assimilated by most plants. Moreover, this form of nitrogen can also be processed by bacteria to yield nitrate, providing us with an additonal – slow release- mechanism for nitrate supplementation. Several research groups have asked themselves if urea would bring any significant benefits to hydroponics crops. Of particular interest was a study published by Oda *et al*, dealing with the effects of Urea and nitrate fertilization in hydroponics crops using both organic (peatmoss and baggasse), inorganic (rockwoll and sand) media and pure NFT systems.

After doing a study with several concentrations of Urea and Nitrate -both by themselves and combined – this research group found out that Urea does not improve crop yields in NFT systems and indeed pure nitrate does the best job when no media is in place. When media is introduced, organic media shows a faster Urea to Ammonia conversion but Ammonia to nitrate conversions are faster in inorganic media. However, the effect of Urea remains poor in the sense that nitrate-only crops outperformed almost all crops except for some plants grown with small quantities of Urea which proves to be beneficial in the same way as small additions of ammonia are already known to be.

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So in the end, is it worth to add Urea to a hydroponic formulation ? The scientific evidence says that Urea does not have any clear beneficial effect that could not be gained by a small addition of ammonium salts, something which has already been confirmed by several studies done on different plant species. If you are planning on starting a new hydroponics crop adding about 5-10% of your total nitrogen as ammonium may prove to be beneficial but any addition of Urea seems completely unecessary.

Of course, further research on this subject would be needed to know the effect of nitrate/ammonium/urea combinations to know if the beneficial effects are a sole consequence of the presence of small quantities of ammonia or a virtue of the "regulatory" effects introduced by Urea as a slow release ammonium fertilizer.

Hydroponic Tomato Formulations – Nutrients for Every Growth Stage

One of the most interesting things that can be done once you know how to prepare your own hydroponic nutrients (check out my free ebook on the right hand menu) is to make formulations for the different growth stages of your crops. Certainly the variation of several nutrients along the different stages of a plant's life will guarantee optimal production with better than average results. In the beginning it certainly isn't very clear how you should vary nutrients and careful care about the amounts – particularly the ratios between nutrients – have to be taken into account in order to have the best possible results. On today's post I want to talk a little bit about hydroponic tomatoes and how we can design a very specific "feeding schedule" with small modifications in our nutrient

formulations for the whole growing process of this plant.
When you are growing plants, their needs are obviously not the same along all their growing stages. In a similar way as a 5 year old human doesn't need the same nutrients as a 16 or 52 year old, plants that are just germinating and plants that have been flowering or have just begun their fruiting have different nutritional needs. In tomatos, these differences manifest themselves as different demands for the different nutrients. For example, demand for magnesium, nitrogen and potassium increases as the plant grows older as more nutrients are needed to develop more live material. However some needs – such as those of micronutrients – remain fairly constant as the demand for most of these ions is not increased radically as the plant grows.

Of partiular usefulness to understand how to improve your tomato crop by developing a formulation schedule is a study done by the university of Florida by Hochmuth *et al*. The study shows the design and application of a feeding schedule to tomato crops from transplant to fifth cluster development, changing nutritional input as the plant develops. You can access this study here and look at all the different formulations developed for different stages of tomato growth. By using the ppm values provided on this study you can easily prepare nutrient solutions using the spreadsheet provided with my nutrient preparation ebook (available freely).

When you analyze the nutritional formula given above you can see how some nutrients are increased gradually while some are increased in large steps. You can also see how some ratios – like the N/K and Ca/K relationships – vital to the development of healthy tomato fruits, develop as the plants reach a more mature stage. In the beginning, small quantities of nitrogen (< 70 ppm) are available while in the end this quantity is increased to 150 ppm falling in line with the demand of a much larger fruit-producing plant. Hopefully with the above guidance and reasearch article you will be able to start some customized nutrient scheduling for your tomato crops to improve their yields, making sure that your plants get the most out of the nutrient formulations they are using.

How to Have a Constant pH in Hydroponics – No More Corrections!

Adjusting pH, the endless chore

Plants in recirculating systems will change the pH of their solutions through nutrient uptake. This means that the pH of a recirculating hydroponic system will be inherently unstable and will require constant corrections. We usually carry out these corrections through the use of strong acids or bases, such as the commonly used pH up/down solutions we buy at stores. This makes the process of pH adjusting repetitive. Although many people have implemented automated systems for pH correction, these systems have potential for failure, especially due to sensor calibration or failure issues. Ideally, we would want a completely passive solution to maintain the pH of our hydroponic nutrient reservoir.


A weakly acidic ion-exchange resin used for pH control

Chemical buffers

There are several ways we can tackle the problem of shifting pH. Chemical buffers are a potential alternative. I proposed the use of a citrate/carbonate buffer in a previous post, but this buffer does not work due to the microbial and plant metabolism of citrate ions, which pushes the pH up. Carbonate/phosphate buffers offer a better alternative, but there are inherent limitations in the strength of these buffers due to the limitations in phosphorous and carbonate concentrations that plants can tolerate. This means such buffers are usually restricted 1mM or lower concentrations – not able to compete with plant uptake.

The most popular choice in the research community are MES buffers, which can be used to keep the solutions at stable pH and can be used at concentrations even exceeding 10mM. The problem with these is that they can cause problems in some plant cultures and they can also become extremely expensive for large growing systems.

Ion exchange resins

How do we keep pH constant without using any chemical buffer?

The solution comes in the form of weakly acidic ion exchange membranes. These substances contain polymer-like matrices which have functional ion attracting groups on their surface that react with acids and bases in solution and provide you with a constant pH level.

These composites are insoluble and the only thing they need to be efficient is to have solution passed around them frequently. It is a matter of putting them in a place where fresh passing solution will be in contact all the time – such as near or connected to a high-flow pump – and that's it, no more pH problems, no more additions to control pH, problem absolutely solved. As the solution passes through the material, it will be able to react with the ion attracting sites in the polymer to stabilize the pH. These compounds have been studied in the literature and given good results (1, 2, 3).

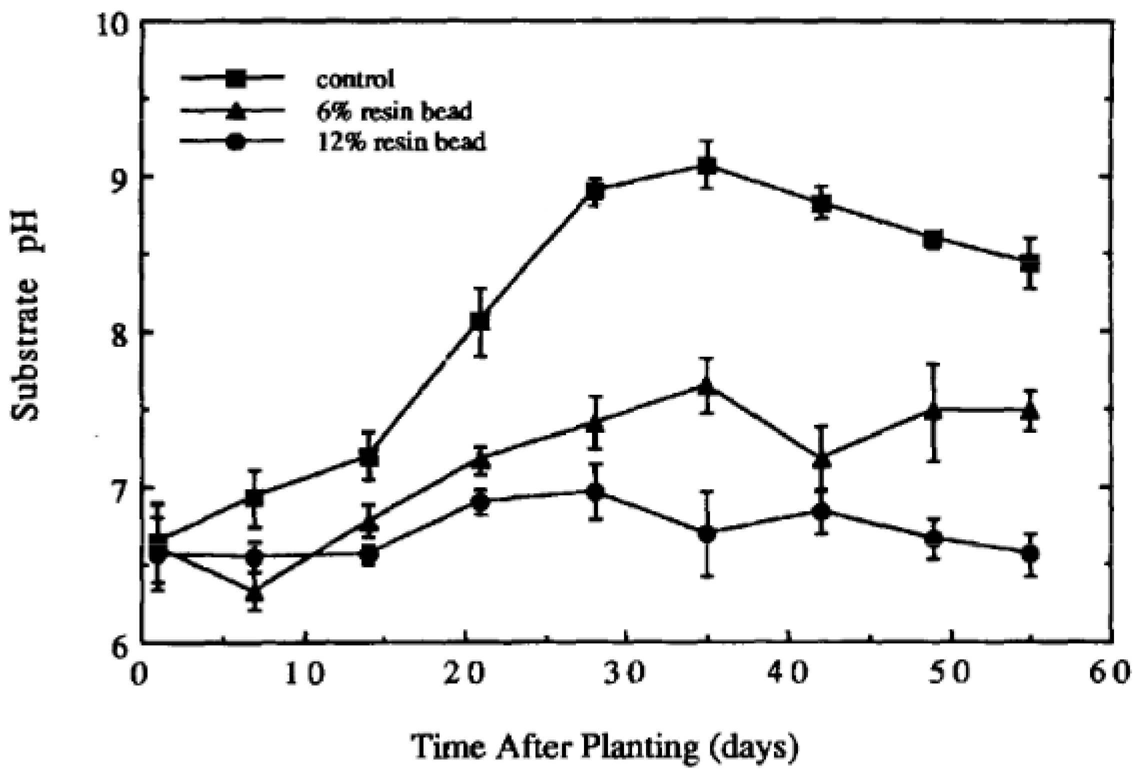

Fig. 2. Effects of cation-exchange resin beads on root-zone pH in solid-matrix hydroponic systems. Vertical bars represent SE of the mean with data combined from two experimental trials.

Taken from this paper. In this research, an ion exchange resin was used as part of the media. You can see how the 12% resin media kept the pH from becoming uncontrollable.

In particular researchers in the 1980s tested weakly acidic ion exchange resins, like Amberlite IRC-50. One of the problems with their use was that these resins can have significantly high affinity for Ca and Mn, which means these cations need to be added in excess or replenished if the plants show problems with their uptake. Note that the Amberlite IRC-50 ion exchange resin is no longer available. For a public list of currently available resins, you can refer to this link.

My experience

I have tested ion exchange resins extensively in recirculating systems and they can provide you with high pH stability through time, especially when the plants are pushing the pH up. This is the most common steady state of a hydroponic system, as most plants will make solutions more basic through their nitrate uptake. Since the loaded state of the resin is acidic, they have their maximum buffering capacity towards pH increases in this state. As the resin gets used from this state, it gains buffering capacity against the other direction.

Another advantage of the resins is their ability to be regenerated a very large number of times. In weakly acidic ion exchange resins, this is done by soaking the resin for a short time in a strong acid. Normally muriatic acid is the acid of choice, as the chlorides of most cations trapped in the resin will be soluble. While other acids could be used, they might form precipitates with some ions trapped in the resin, especially Ca.

The resins in their charged state are naturally bad at buffering against pH decreases in the nutrient solution as they have only acid to contribute to the solutions. While protection to the downside will be created by the resin with time, you might need to modify the starting state of the resin if you want this protection from the very start.

Conclusions

Weakly acidic ion exchange resins are a great way to provide stability to a recirculating hydroponic system, they are also low cost and can be regenerated easily. They work best when plants push the pH of the nutrient solution up initially and do require modifications for cases where guards against pH drops are required from the beginning. Depending on the exact chemistry of the resin there might also be some issues with capture of some cations, like Ca/Mg/Mn, reason why it is important for us to monitor the plants closely when these resins are initially used.

Have you tried any weakly acidic ion exchange resins in your recirculating hydroponic solutions? Is your pH stable? Let us know in the comments below!