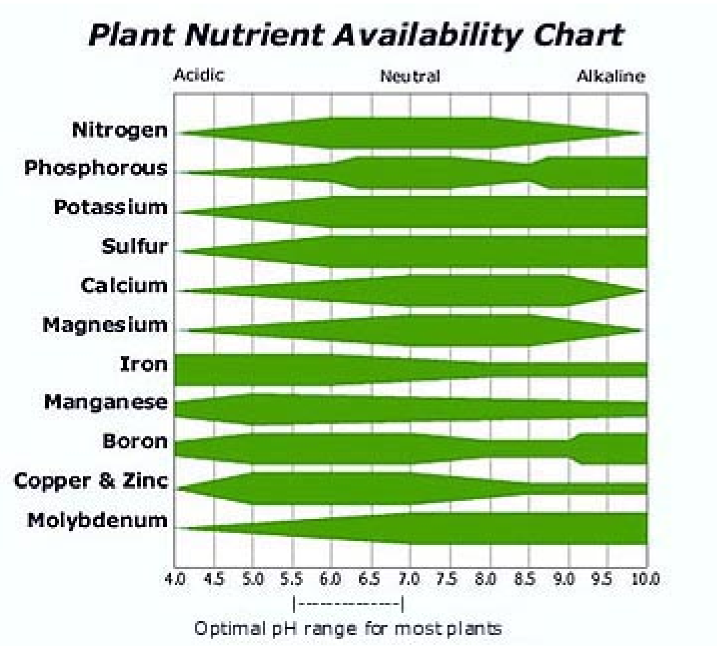
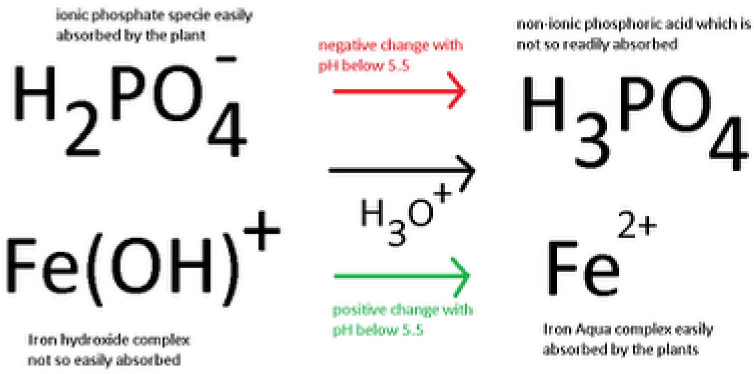
Understanding pH in Hydroponics – Part No.2

Yesterday – on the first part of this article – we talked about the nature of pH, the origin of pH changes in hydroponics growing and why these changes happen with time within a hydroponic culture, I also talked a little bit about how to prevent pH changes by building a balanced solution with a given percentage of nitrogen given as ammonium. On the second part of this article I am going to talk about the adaptation of plants against pH changes, why certain pH levels are needed and why there is an important over-focus on the importance of pH which does not need to be maintained in ranges as narrow as most growers believe.

What is the ideal range of pH for plant growth ? The fact is that plants can grow ideally from a pH of 5.5 to about 7.0. Above or below these values certain changes start to happen within the chemistry of the solution that makes nutrients less available to the plant. The large importance of adequate – yet not excessive – control of pH values is to maintain an optimum absorption of nutrients for your plants. When we go below a pH of 5.5 certain nutrients like iron become very readily available while nutrients like phosphorous and nitrogen become much less available. This lack of availability has two main causes. The first one is the overall change of chemical species within the solution, with the newly generated species being difficult or impossible to assimilate by the plant while the second one is that species that become extremely available generate a strong antagonic effect against some nutrients. For example, iron is antagonic with phosphorous and with a pH decrease below 5, the absoprtion of iron becomes extremely easy and therefore the aborption of P becomes more difficult, the overall formation of acid phosphate species which are also not so readily available by the plant further reduces P availability. An image shown below gives you a good idea of the availability of nutrients for plant growth as pH changes.





However most growers tend to believe that the pH level of their nutrient solution is the pH level that plants have around their roots, something which is actually not correct in the sense that plants have evolved local pH adaptation mechanisms to survive to changes in soil pH. When you measure the pH of your nutrient solution you are measuring the pH of the “bulk” while the pH of the actual root-zone of your plants might be within the ideal zone for nutrient absoprtion. Therefore growers usually underestimate the actual capacity of their plants to correct pH and spend an enormous amount of time tinkering with pH to make it “ideal”.

The fact here is that plants do not like abrupt pH changes like those that happen when you add pH up/down to continuously adjust your nutrient solution’s pH levels. Plants can deal perfectly with a slow pH increase caused by nutrient absorption from 5.5 to 6.5 but when you – in a matter of seconds – revert the pH back from 6.5 to 5.5 in a matter of seconds you are causing your plants significant levels of stress since they are simply not used within their natural environment to such quick pH changes.

The easiest way I have found to deal with pH is to simply not obsess with it. Most solutions that are well balanced and contain about 10-15% of the nitrogen as ammonium and about 20-40 ppm of phosphorous will adequately contain pH within the 5.5 to 7 pH region from the beginning of your nutrient cycle to the time when the nutrient solution has to be changed. As a matter of fact – beyond the initial adjustment – the changing of pH can be avoided if the nutrient solution is adequately formulated and given in a quantity of at least one gallon per plant. Plants develop well around these pH levels and the improvement you gain from obsessing about perfect pH zone levels will be lost by the stress you put into your plant roots with pH corrections. Of course, there are easy and almost perfect solutions to pH control like the method using ion exchange resins I mentioned in a previous post. A method that mimics the way in which pH is naturally buffered within soil.

Therefore if you want to have a great hydroponic crop with little maintenance and a very good yield I would advice you to prepare your own nutrients taking pH-self balancing and adequate nutrient ratios into account. Certainly this method will give you a lot of control over your composition and a great saving in solution costs.

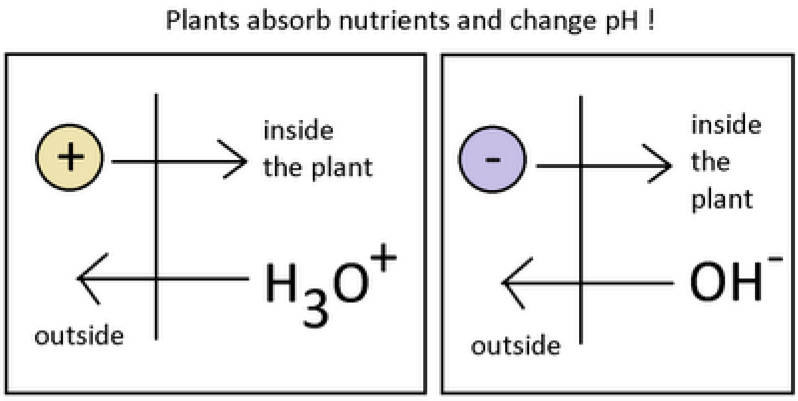
I hope that after reading these two posts on pH in hydroponics you have now grown a much better understanding of how pH is, how it works and how it evolves in a hydroponic culture. It is very important for you to understand that pH plays a vital role in nutrient absorption but that obsessing with strict pH zones is not beneficial for your plants in the sense that constant additions that cause quick changes in pH values cause stress to their root zone. Adequate nutrient design and a good understanding of how nutrient interact is therefore important for the correct use and low maintenance of a hydroponic crop.

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)

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).

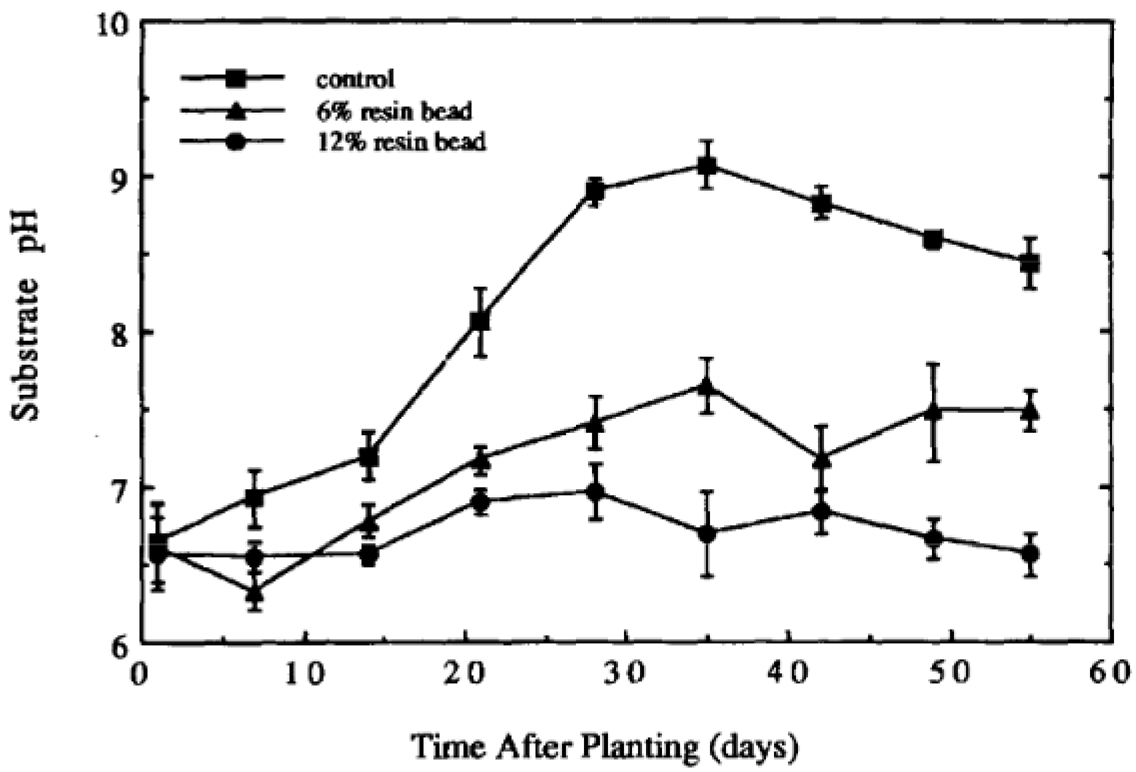


Fig. 2. Effects of cation-exchange resin beads on root-zone pH in solid-matrix hydroponic systems. Vertical bars represent SE of the mean with data combined from two experimental trials.

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!