ELTON ROBERTS & MALCOLM BURLEIGH

Watering Systems for Success in Growing Plants, Using Low pH and Ammonium Nitrogen

"As the water is, so then shall be the soil."[3]

Abstract

Over several years we have seen our succulent and other plants start growing as they never have before. We attribute this vast improvement to:

- Dropping the pH of our water to between 5.0 and 5.5
- Adding small constant quantities of ammonium nitrogen (50 – 200ppm) along with phosphorus, potassium and the necessary micro-nutrients to our water during the growing season.
- During the off season when it is necessary to water, low-pH water, between 5.0 and 5.5, is still used for our plants without the fertilizer elements.
- Setting up a watering system that can readily and easily handle and deliver the proper water and nutrients to plants.

We have seen a significant improvement in the health of our plants, including improved conformation of overall general plant growth and structure, as well as leaf, spine, and root formation. Most significantly we have seen vastly-improved flowering and seed production. This latter effect is quite amazing, the plants not only bloom more, but for a longer time, and their flowering period is often shifted to longer and wider time spans. At the same time, smaller and younger plants will bloom sooner and more frequently.

Foreword

In the two articles (1,2) that we have written for the Cactus and Succulent Journal, we have given arguments for using low-pH water and ammonium nitrogen as a standard practice for cacti. But we have not put the whole story together and we feel that it would be good simply to give more complete instructional details to growers. We have been using this watering regimen on all of our plants: all cacti, other xerophytes, popular garden plants, alpine plants, forest plants, tropical plants, and vegetables. We feel that our techniques may be used successfully on virtually all plants.

The only genus that seems not to do well is Selaginella. These are strange plants related to the mosses, often found in xerophytic places. These plants do well with low-pH water, but only with rainwater. One of us is continuing to work on these issues.

pH and Bicarbonate

Bicarbonate toxicity – The need for low pH is to counteract the presence of bicarbonate in our water. This ion occurs in fairly high levels in most waters either due to addition into municipal water supplies to prevent pipe corrosion or from alkaline wells. Constant watering with municipal water, and many well waters, can cause plants great harm due to the accumulation of this ion into the soil. These levels can vary widely depending upon the water source. [1]

There are several ions that are toxic to plant roots. Sodium chloride is the most familiar, and agricultural workers are well aware of its effect upon crops. Many civilizations have risen and subsequently fallen because their soil became too salty due to irrigation with saline water. There are many crops that will tolerate higher salt content. but too much salt will lead to their eventual demise.

Another salt turns out to be much more toxic than sodium chloride. This is the bicarbonate ion which we will refer to as "alkalinity" since any time an alkaline ion gets into the water it will eventually become bicarbonate by its reaction with atmospheric, carbon dioxide. An illustration of this is seen in the root growth of radishes with varying concentrations of sodium chloride and sodium bicarbonate. The toxicity of bicarbonate is about 3.5 times as great as chloride. [(3)]

Relative elongation of radish roots in two different solutions

SOLUTION	0	5	10	50	100	200
NACL	100	94	86	81	75	60
NAHCO3	100	90	78	36	18	2

Solution concentration in meq/l

The problem arises when we continuously apply alkaline water to our plants. Bicarbonate concentrates in the soil creating an environment that prevents the roots from taking up water along with the necessary growth elements.

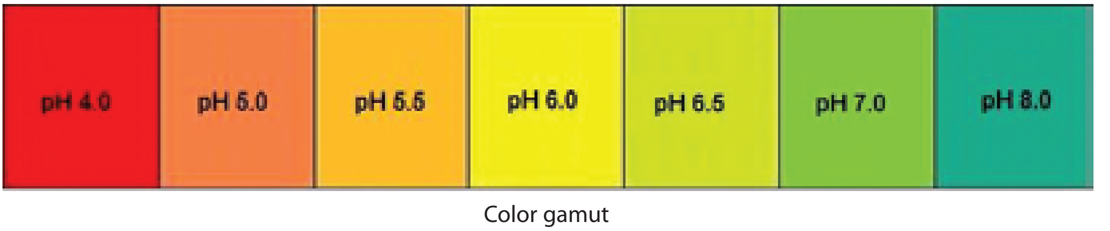
Fortunately, although bicarbonate is several times more toxic than sodium chloride it can be readily removed by simply adding acid to the water. The most difficult part is to know just how much acid to add to the water. Just the right amount must be added to inactivate the bicarbonate in water. Since the bicarbonate levels vary widely depending upon the water source, we cannot make a blanket recommendation on how much acid to add.

In order to determine how much acid is needed, one could either use a pH meter (ca. $150) or more simply use a pH indicator. Excellent pH indicators may be purchased for $7-10. These are available from hydroponics suppliers. They use a combination of Methyl Red and Bromothymol Blue. Methyl Red goes from red to yellow starting at a pH of 4.8 to 6.0. Bromothymol Blue goes from yellow to blue at a pH from 6.0 to 7.6. In this way they form a natural rainbow spectrum of color which is fortuitously in the right range of our interest. We recommend using the cheaper indicator and shooting for a pH between 5.0 and 5.5 (salmon red to orange). These indicators are sold in small dropper bottles with a small test tube for holding a water sample. One drop in the test tube will suffice to tell what the pH is. We do not recommend pH paper or litmus paper; it

Commercially available pH indicators

BROMOTHYMOL BLUE	6.0	7.6
	Yellow	Blue
METHYL RED	4.8	6.0
	Red	Yellow

Commercially available pH indicators: General Hydroponics and Sunleaves.



Color gamut

is not accurate enough for this activity. Once it is known how much acid to add, it should only be necessary to periodically check the pH.

In order to find these either search the Internet (SUNLEAVES pH TEST KIT DROPS) or E-mail Elton at (1cactus1@verizon.net).

Types of Acid—It does not make much difference which acid is used. We know that people practicing hydroponics often use either phosphoric or nitric acid. In this way they add phosphorus or nitrogen while adjusting their pH. Our best advice is to balance off cost, convenience and safety. Sulfuric acid is the cheapest acid and we recommend that for larger operations. It is readily available but must be handled carefully; clothes can be ruined with it. (Always add the acid to the water, not the water to the acid!) Acetic acid (white vinegar) works well and is quite safe. Sodium Bisulfate is often used to drop the pH in swimming pools and also can be used. This is a solid, and is very convenient for medium-sized operations. The type of acid used is not particularly important, but do not use hydrochloric or muriatic acid since they would leave a salt residue, and plants do not like chloride.

pH rebound – We have seen that after a day or so the pH will rebound slightly. This is nothing to worry about. It is just some CO_2 evaporating the water.

Organic acids such as acetic acid (vinegar) are prone to bacteria eating them. If acetic acid is mixed with water and left to sit for some time, the pH level may climb. The water may then become cloudy. The bacteria in the water is growing and utilizing fertilizer and acid to live on. If this happens, clean the water container and begin anew. When these acids are added to water, the solution should be used quickly.

Reactions are not the same with sulfuric acid or sodium bisulfate. It is possible to control the bacterial growth by adding some hydrogen peroxide. **Do not add bleach to water! This is dangerous. It reacts with the ammonium to form a toxic chemical.**

Plants that live on alkaline soil? – We receive many questions regarding plants that either live on limestone, gypsum, or similar alkaline soils, such as Turbinicarpus, Ariocarpus, Pelecyphora, and other genera. The pH reaction of those soils is high, ca. pH = 8. (4) People then water these plants with high-pH water and find that these plants are "difficult". So just what is happening? How do they survive in this situation of high alkalinity?

The water they get from rain is acidic. When it rains they are able to quickly absorb the water and nutrients from the soil. The pH of the rain may vary from 4.8 to 5.6. As time passes, and the water evaporates, the pH eventually increases. Then, the cacti stop absorbing water and eventually go dormant. Our experience with limestone soils suggests that the progress to higher pH is on the order of several days to a week. Although these plants grow in calciferous soils of limestone and gypsum, they all respond extremely well to low-pH water and very poorly to high-pH water. Although they tend to grow slowly, they are not difficult plants. If the right culture is followed, these plants will be greatly rewarding.

Ammonium Nitrogen and other elements

There are three types of nitrogen we can add to our soil:

1. Ammonium $(NH_3)^+$
2. Nitrate $(NO_3)^-$
3. Urea $CO(NH_2)_2$

We recommend ammonium over both of the others. We feel that urea cannot be utilized in xerophytic soils. Nitrate may be OK, but we understand that it is not as quickly absorbed by the roots. In addition to that, it is more expensive. We are recommending that ammonium sulfate be the primary nitrogen source. It has the highest amount of nitrogen other than urea (47%) or ammonium nitrate (35% N), which is no longer commercially available due to its explosive properties. After urea, it is the cheapest source we have found.

Commercial Nitrogen costs JR Johnson (10/2009)

NITROGEN SOURCE	$/LB	% N	$/LB FOR N
UREA	$0.33	46.7%	$0.71
AMMONIUM SULFATE	$0.42	21.0%	$1.98
CALCIUM NITRATE	$0.60	17.1%	$3.51
MAGNESIUM NITRATE	$0.80	18.9%	$4.23

Formulations—Formulations may vary depending upon location and availability. We are advocating ammonium sulfate in conjunction with a soluble, balanced fertilizer and constant application throughout the growing season, using a watering system to deliver the fertilizer. Many

	AMMONIACAL	NITRATE	UREA
	% N	% N	% N
PLANTEX 20.20.20	3.85	5.9	10.25
GROW MORE 20.20.20	3.9	5.9	10.2
PETERS, NOW CALLED JACKS CLASSIC 20.20.20	0.0	2.1	17.9
TECHNIGRO 20.18.18	4.8	5.4	9.8
TECHNIGRO 20.18.20	4.6	6.0	9.4

of the fertilizers have their own pH adjustment, so it's better to adjust the pH after the fertilizer is added.

There are many commercial fertilizers with balanced N, P, and K. Phosphorus (P) is always present as phosphate, and potassium (K) is always present as potassium ion. However nitrogen (N) will be split up into three groups: ammoniacal, nitrate, and urea. These formulations are frequently based upon chemical cost. It is advisable to include the commercial fertilizers into the formulations since these contain the needed micro-nutrients.

High humus soils—Those who use higher humus soils will have to add more nitrogen since the humus content of the soils may use up the available nitrogen. For this reason we recommend higher (ca. 2x) amounts of nitrogen for high-organic soils.

Formulation for high-humus soils (30gal = 114L)

MATERIAL	CC	TBSP.
COMMERCIAL 20-20-20 FERTILIZER	60	4
AMMONIUM SULFATE	120	8

This is about 200ppm N and 100ppm P and K. Discount the urea portion of this fertilizer since is will be washed through the soil.

If a urea and nitrate free fertilizer is desired, here is an example of what can be done. There are several types of "bloom" producing fertilizers with very high phosphorus content such as Schultz 10-54-10 that normally have no urea, and the nitrogen source is Mono-ammonium phosphate. These contain micro-nutrients. potassium sulfate (K_2SO_4) needs to be added along with ammonium sulfate in order to attain a balanced formula. This is also about 200ppm N and 100ppm P and K.

Urea-free formulation for high-humus soils (30gal = 114L)

MATERIAL	CC	TBSP
SCHULTZ 10-54-10	20	1.3
POTASSIUM SULFATE	20	1.3
AMMONIUM SULFATE	90	6.5

High mineral soils—These formulations will suit mineral soils such as ones made up of limestone, pumice, perlite, and decomposed granite (no humus material). They will also contain the needed micro-nutrients. Formulations of 20-20-20 fertilizer may contain large amounts of urea as its nitrogen source, which will be washed out of the soil.

Formulation for high mineral soils (30gal = 114L)

MATERIAL	CC	TBSP
20-20-20	30	2
AMMONIUM SULFATE	30	2

This is a urea-free formulation for high mineral soils. These contain roughly 50 PPM of the three elements N, P, and K.

Urea free formulation for high mineral soils (30gal = 114L)

MATERIAL	CC	TBSP
SCHULTZ 10-54-10	15	1
POTASSIUM SULFATE	15	1
AMMONIUM SULFATE	30	2

Ammonium sulfate—Many forms of ammonium sulfate are not completely soluble in water. As a result of this, plugged nozzles may be problematic. Before buying large quantities of ammonium sulfate or any fertilizers, it is a good idea to check their solubility in water. It may be difficult to find,but "Sprayable" ammonium sulfate is totally soluble. This material is used as an adjuvant for spraying Roundup® type chemicals. The "Sprayable" comes in 51 lb bags for formulation with Roundup® type chemicals. You may also be able to find ammonium sulfate in 50 lb bags listed as "fines" or as "crystals". This type may also be suitable. It may be cheaper, so check the prices and shop around.

There is a time-release form and the cheaper, pelletized form, both of which are not totally soluble. The pelletized form leaves a gummy residue, which will clog up watering nozzles. We have also seen several other commercial fertilizers with this problem. It doesn't matter which type of ammonium sulfate is used for dip and pour methods.

If these solid materials are being compounded, it is generally a good idea to thoroughly mix the components. Stratification may occur if some of the particles of the fertilizer have very different particle sizes. Ammonium sulfate is not hard to find either in nurseries, horticultural stores, or on the web.

Watering systems

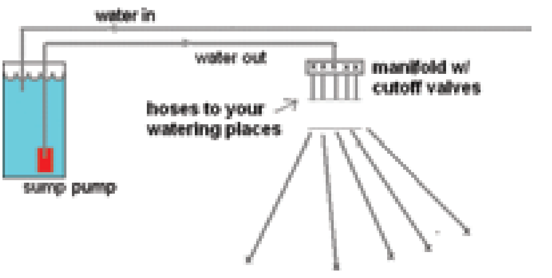
In order to benefit from low pH and the proper amount of fertilizer, the delivery must be controlled. We feel that this is a critical step. We strongly recommend setting up a watering system for application. Its size will be dictated by the size of the operation.

Dip and Pour—If just a few plants are on hand, then a dip and pour may be accomplished from a large container, but one may quickly tire of this since it is laborious. I use cheap, plastic, five-gallon buckets with polyethylene cups. These are handy since they float in the water. This is also very handy if some plants are in an out of the way place. Some people prefer a large watering can, and just about anything is possible as a container. The container though, should be plastic. One may want to prepare a concentrate of acid and fertilizer so that just a certain amount of liquid is put into the concentrate.

Sump Pumps—The basics are shown below for a sump pump setup. Water goes into a tank of known volume. The tank size should be such that all plants can be watered with less than one tank fill. The tank ought to be well covered to prevent leaves and bugs from getting in. Acid and fertilizer should be readily added to the tank as it is being filled. I keep my acid dissolved in a glass bottle and have another bottle where I can pre-dissolve fertilizer. I periodically check the pH to see if it has shifted or if I have made an error. I have several 1/3 cup and 1/4 cup kitchen measurers for my activities.

"Plumbing 1A"—For these and other larger systems we will start with some simple advice on plumbing. In a high rain area, they will be available in every hardware store. In a dry part of the country one may have to shop around for these items or find them on-line. Sump pumps are basically used to pump water.

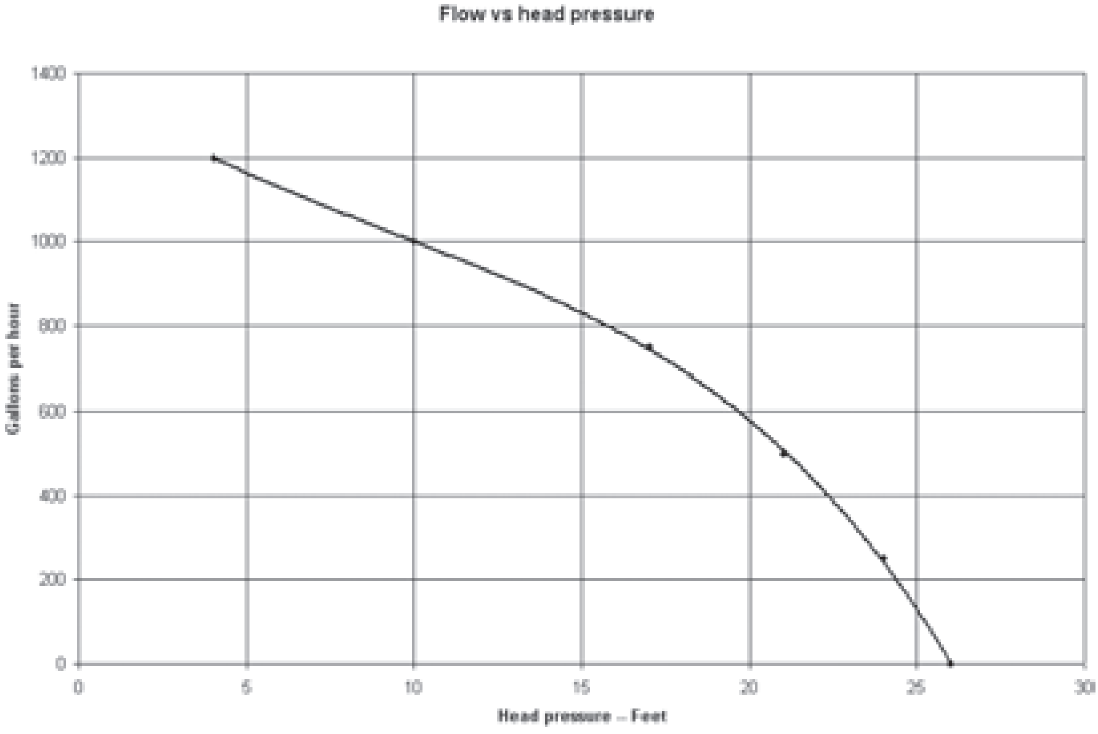
Sump Pump Layout



1/3 hp Sump Pump

Plastic screen base

These are known as volume pumps and do not work well at a high back-pressure. If water is being pumped up a hill, if a very long hose system is



being utilized, or if the hose diameter is small, flow restriction will occur. Changing from a hose with a 3/4" ID to one with a 1/2" ID will decrease the flow rate by greater than a factor of two.

On the other hand, volume pumps are cheap at $100 or less and almost indestructible. They come in various horsepower ratings, but the volume flow can still be restricted even with a high-horsepower pump. I have two 1/4 hp pumps, one ¼ hp pump and one ⅓ hp pump. If a lot of sprinklers are being used, a higher horsepower pump may be required. Watering areas sequentially, rather than everything at once is advisable. Cut-off valves are useful in these applications.

Some pumps are meant for draining areas, which periodically become flooded. These pumps have a float valve that will shut off the pump when the water level drops. Avoid using this type for a tank since they will not empty the tank. If one with a float is currently in use, it is often easy to inactivate the float, since it is usually an add-on feature for the pump. Most sump pumps have heat shutoff switches in case it's run too long.

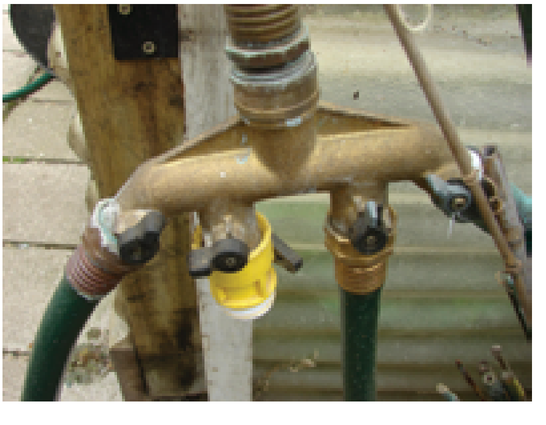
Fittings – Normally the pumps come with a fairly large bore fitting from 1" to 1.5". With most pumps, an adapter will be need to allow set up to a garden hose.

All of these adapters are soft plastic, so it is advisable to add a hose extender with a shut-off valve. This way, when a hose is attached, which often has harder brass fittings, the adapter will not easily be cross threaded.

Pump maintenance— pumps run at a fairly low pH under water. They should be periodically maintained. The best pumps have an acid resistant body either of plastic or stainless steel. Avoid pumps with aluminum housings as they will corrode in water. Since the pump remains in water, it must be grounded to avoid stray currents.

Tanks—One of the best tanks for a small system, less than 100 gallons, is a plastic garbage can. Highly-durable garbage cans should be used; the

Cut-off valve for watering only certain places



no adapter

with adapter

with extender

thicker plastic will last longer. I have gone through several cheap, plastic, garbage cans which have turned into holders for my potting soil during the winter, because they had developed leaks. There are many other possibilities. Plastic 55-gallon drums are available. I have a 30 gallon drum. However, if nothing else is available, a very good, plastic, garbage can may be used. Don't use galvanized cans though; they are not good for this activity.

Hoses and connections—In an area with little frost, installation of PVC pipe is a definite advantage. I use regular hoses since they can be taken down or put up easily. Since I live in Minnesota with frost possible from October to May, I have found hoses to be better; freezing will not ruin them. It is best to buy good hoses. With the lower pressure that occurs with sump pumps, the hoses will have a tendency to kink and constrict the flow. I also use spiral hoses with a ½" ID to pump water into one of my smaller greenhouses since I don't need a higher flow there. I always use shut-off valves on all of my hoses and deliver water from a spray nozzle so that there is a back pressure that keeps the hoses from kinking.

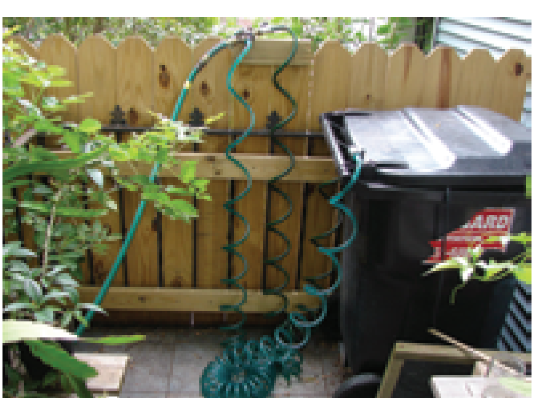
Watering—I water one area at a time. When a hose is moved from one area to another, it should be shut off with a shutoff valve, preferably attached near the nozzle. In this way maximum pressure will be maintained in the hose and kinking will be avoided. Always check the water level in the tank at the onset of watering. Running pumps dry can destroy the pump. When the tank is depleted of water, quickly cut the power. This will not harm most pumps. I have had a couple of pumps run dry for about 30 minutes. I thought I had ruined the pump but it had a heat override.

Nozzles—I have noticed that nozzles, as well as the male and female connectors of the hose, are subject to corrosion. Other spray parts, which have a zinc type metal in them, are even more subject to corrosion. Plastic nozzles and other fittings will last a lot longer for this activity.

Filtering – In all of my hoses I use a filter screen to prevent the spray nozzles from getting impacted with particulates such as leaves, etc., from the tank. These are available in garden shops.

Siphon mixers—We do not recommend siphon mixers since the variability may be way too high

Garbage can tank showing hoses



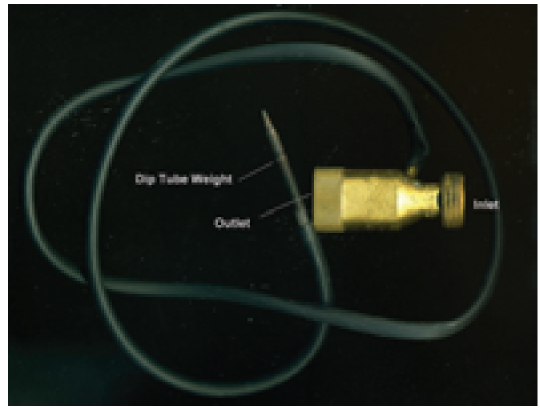
Water in and water out hoses shown

Nylon plastic manifold

and either burn plants with high or low pH. A Syphonject® system or similar type of siphon such as Hozon® may work. This will be less than $25. However, we must warn that the dilution rate is heavily dependent on the back-pressure. Thus the nozzle, hose size, flow rate, and hose length are critical factors that must be taken into account whenever they are changed. Typically the dilution rates are ca. 16:1.

Large Injectors—For larger operations we suggest the use of a Dosatron® or similar injection devices. These run in the $400 range. They are set up to inject liquid into the water stream. They can adjust the dilution from 1:66 to 1:500

Hose washer/screen pack



Hozon® Injector

and can deliver up to 20 gallons a minute of water. They do not use electricity to run.

There are smaller units and much larger units. The 1:66 means that it will take one gallon of concentrate and make sixty-six gallons of solution. Or the 1:500 setting will turn 1 gallon of concentrate into 500 gallons of solution. The tank shown below holds 300 gallons of concentrate, which when run through the Dosatron at 1:115 delivers 34,500 gallons of mixed water. The tank contains fertilizer and enough sulfuric acid that, when run through the machine, gives a pH of 5.0 to 5.2. The plants receive a weak solution of fertilizer every watering. From the Dosatron is a 1" line going to the hot houses.

Dosatron Detail

How to water—There is a school of thought that tells us not to water plants from overhead because:

- watering plants over head will make the plants rot because the crowns may hold water and they will rot.

Dosatron and Tank

Sprinkler

- drops of water on the plant skin will cause sunburn.
- watering overhead will cause black spots on the plant.
- wooly plants will hold water which will rot the plant.
- watering overhead will leave water spots on the plants and the spots can damage the plant's skin.
- seed pods on the plants will get wet and rot the plant.

We feel that these caveats are simply without merit. We recommend overhead watering because rainis natural overhead water. In greenhouses or hothouses, dust settles on everything. Mites live in that dust and thrive in the dry environment. When water is applied from overhead, the plants are freed of dust so the mites are being deprived of their favorite place to live.

For larger operations, the best way to water is with a sprinkler system. It insures that the plants get an even mount of water. The best sprinklers deliver a fairly fine spray. In this way any top dressing is not hit too hard and it does not get knocked out of the pot. It is better to have some over spray than to have a spot that continually receives too little water. The Roberts Irrigation sprinkler (no relation) is an excellent choice.

Other plants—This acid/water solution can be used for all horticultural operations. Vegetables will thrive. We consider this to be a very general application.

What to expect from your plants

Both of us have seen amazing results from our own plants. One of us (E.R.) has a fairly large cactus nursery and lives in the Central Valley of California in a fairly mild climate. The other (M.B.) lives in Minnesota, which is about as harsh a climate as one could have for cacti. Our water bicarbonate levels are fairly close.

We have basically seen the same results on our plants. Much better growth, more robust spination, and better conformation on all of our plants. The increase in flowering for our plants has been nothing short of amazing. Many difficult plants are now easy.

We and all of our correspondents, switched first to the low pH regimen and a few years later to ammonium sulfate. We were lucky that we did not choose to add ammonium sulfate first. If we had done that without first dropping our pH, we would not have discovered the ammonium effect and would probably have stopped there. We would have been just as ignorant as before. Dropping the pH though, did allow us to take advantage of the fertilizer elements that were in the soil at that time.

Corroboration

One of the problems with corroboration is: Who wants to take "before" photos of half-dead cacti? We all would rather take photos of plants that have so many blooms you can't see the plant, so for this you will have to trust us. It's like those before and after ads in the magazines either for body building or weight loss.

Our correspondents switched first to a low pH regimen, and subsequently have added ammonium sulfate nitrogen. The differences they see are very illustrative. One of the most important issues is the initial quality of the water. Most of our correspondents have alkalinity (bicarbonate) levels of about 1 to 2 meq/li. They report that the change to ammonium sulfate is much greater than the effect of lowering the pH. Their comments were that the change in pH was good, but the effect of going to the ammonium sulfate was by far the most significant. They would have seen a completely different set of circumstances had they first gone to ammonium sulfate and then dropped their pH. In this case, the second step would be enormous and the first would have shown nothing.

To illustrate this, one grower has a very high bicarbonate level of 9.7 meq/li. In addition to this, her water contains about 42 ppm nitrate. Her comment was, "Before lowering my pH, a lot of my plants didn't grow much, or not at all and finally puked out, especially the 'white' (haired) cactus. I had plants for years that just didn't grow! Lowering the pH to the proper level has made old struggling cacti plump up and look healthy instead of mealy bug ridden. After adding the ammonium sulfate, the plants bloom a lot more than they ever did. But the biggest difference I would say was the lowering of the pH for the overall health of the plants."

It seems as though she was getting plenty of nitrogen before she dropped her water pH but it was not being utilized until after she had lowered her pH. The boost from ammonium then was less. However, it would appear that the ammonium sulfate is boosting her flowering.

These are quotes from Steven Brack of Mesa Garden, Belen, New Mexico. Steven's bicarbonate levels are similar to ours. Here are some of Steven's comments on acidic water and ammonium sulfate: "I am totally hooked and telling people whenever the topic comes up (that I) am buying lots of vinegar. I see huge changes on limestone plants, everything from Madagascar, all sorts of high mountain plants like Pediocactus, Oroya, etc. My stapelias are going crazy, finally after years of sitting. So far I know of no negative reaction."

Later Steven commented on his use of ammonium sulfate: "I am using ammonium sulfate in every watering, and the results are amazing. It is many times stronger than vinegar. Everything is going nuts and flowering. The new growth is tremendous. It is not soft lush growth but robust, the spines are longer and with more color than anything else I have ever seen. I have played around with various fertilizers and other additives and they at best are a tiny improvement. The vinegar was a good step to help, the plants were very happy. But the ammonium sulfate with vinegar, 'well, that is party time!' All sorts of cacti and succulents are going nuts, I can't begin to mention how everything is really moving. Also the acidified water works wonders for seed germination."

Conclusions and recommendations

The final results for everyone have been similar even though our starting conditions have been quite different.

- The water pH and the amounts of ammonium sulfate and the other elements must be strictly controlled and delivered in constant, even amounts.
- The overall control of the delivery using a watering system is critical. It is necessary to set up a watering system.
- It appears that ammonium sulfate is the main contributor to better flowering and seed production.
- **Don't think that you ought to do one, Low pH or ammonium sulfate, without doing the other.**

During the non-growing season we recommend just using low pH water for plants, if watering is necessary at that time. We feel the low pH regimen also aids in the plants absorption of systemic pesticides into the plant body such as Imidacloprid and the organophosphates.

Low pH and ammonium sulfate are definitely excellent for plants. We have seen from the use of low pH water (5.0 to 5.5) and the use of ammonium sulfate, as part of a balanced fertilizer regimen:

- general improvement in plant health
- vastly improved flowering and seed production
- improved conformation including overall general plant growth and structure, leaf spine, and root formation.
- Neither of us would dream of going back to our old way of operating!

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