Ammonium Nitrogen and Acidic Water for Xerophytic Plant Growth

Foreword — As we write this article we are reminded that 2009 is the 100th anniversary of the development of the Haber process for the cheap conversion of atmospheric nitrogen into ammonia. This was a true revolution in agriculture since at the time, nitrogen was the limiting resource. Fritz Haber received the Nobel Prize for this work in 1918.

Abstract — We have seen phenomenal improvements in our plants: stronger spines and bodies, and much greater flowering and seed production as a result of applying the combination of low pH water, 5.0 to 5.5, and a balanced (NPK) fertilizer using ammonium as the primary source of nitrogen during their growing season. This fertilizer was applied constantly with our water from 50-200 ppm (ammonium) N, and 50-100 ppm P and K during the entire growing season.

The use of low pH water is described in an earlier article[1]. The combination of low pH water and use of balanced fertilizer (NPK) using ammonium ion as the sole source of nitrogen for plants will be discussed. All facets of the lives of our plants have been improved due to use of low pH water and ammonium nitrogen. We have not seen any harmful effects with this regimen.

Elton's discovery — In my time of growing mainly cacti I have seen that not all fertilizers seem to help the plants. When I fertilize, I want it to keep the plants healthy and also looking alive. Over the last 8 to 10 years the fertilizers that I have used have done neither. For years, I could get Plantex fertilizer, which was pH balanced; it kept the plants growing and healthy looking. When I could no longer find Plantex, I tried about a half dozen other fertilizers, but none of the others really kept the plants growing or looking healthy. I figured that the soil needed to be acidic since my water is alkaline. So I bought a fertilizer that contained 1.5% sulfur, which was supposed to keep the soil acidic.

BELOW LEFT Three specimens of *Ariocarpus retusus* before application of NH_4
BELOW LEFT The same three specimens one year after treatment with NH_4

If the soil is damp all he time, as in houseplant culture, bacteria in the soil converts the sulfur into acid keeping the soil acidic. For succulents you let the soil go dry between waterings so the bacteria cannot grow. When I called the fertilizer company, and discovered the secret about sulfur and the bacteria, I knew I had to do something different. That is when I started acidifying my water. Taking the pH of the soil down to a range of between 5 and 5.5 worked wonders on most of the plants. They started growing and shaking off eight to ten years of having to put up with alkaline water.

I have fed my plants full strength with whatever fertilizer I have and have never come up with flabby or overfed plants. In the past I have fed full strength at least six times a year. Other times I feed 1/3 strength and in the heat of summer I do not feed at all as a lot of the plants are dormant.

For years, I have used whatever commercial fertilizer I could get that had micronutrients in it and that had close to balanced numbers like 20-20-20. Of all the fertilizers I used, Plantex was the only one that the plants really seemed to do well on. I have listed below some of the fertilizers that I have used and the break down of the nitrogen they contained. Plantex is the only pH balanced fertilizer that I found. This explains why it worked so well on my plants while I was using it.

	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

% Nitrogen in commercial fertilizers

I contemplated this in the middle of the night, remembering how well the plants look in the desert after a decent thunderstorm, a storm with a lot of lightning where plenty of rain soaks the desert. Thinking about this, I decided that I would give my plants a "thunderstorm." To do this test I decided to use ammonium sulfate, which is a fertilizer that the plants take on very quickly. My plants reacted about as quickly as the plants in the desert. I watered the plants thoroughly and then left on a two week trip. When I returned. I was astonished at how well the plants were growing. They had healthied up amazingly. I have seven hot houses and I only watered that one house with the ammonium sulfate. It was the only one where I saw an improvement in the plants.

Ammonium Sulfate — In California, ammonium sulfate is sold as a quick pick-me-up for lawns. A single application as per instructions and a sickly yellow-green lawn will be a nice dark green in only a couple weeks. That is because it is in a form that the plants can use just about immediately. Another example of how well ammonium acts as a source of nitrogen is that one of the main uses of ammonium sulfate is an adjuvant in herbicides. The explanation is that it is absorbed through the leaves of the weeds and causes quick growth of the weeds. This quick growth is necessary for the herbicide to disrupt the growth of the weed.

BELOW LEFT *Acanthocalycium lopeziae* and below that, *Gymnocalycium grisopallidum*, both prior to treatment with NH_4. **BELOW RIGHT** The same *Acanthocalycium* three weeks after NH_4 and the same *Gymnocalycium* five months after NH_4

We have involved many cactus and succulent growers from throughout the United States and Great Britain in our studies. These growers are basically following our recommended regimens. We have run these studies during the '08 and '09 seasons. We have come to the conclusion that feeding with a weak ammonium sulfate, nitrogen solution every watering is better than a large shot of nitrogen and then little or none for a while. We have seen that the combination of acidic water with a pH of 5.0 to 5.5 and ammonium sulfate in small amounts had made a world of difference in the growth and health of our plants.

We can also report that in general this regimen appears to be good for just about any type of plant. We have not seen any issues with other families or other types of plants from tropical and woodland to alpine plants. They all seem to do very well and their growth and flowering is greatly enhanced. Weeds also do well though.

Urea — We have come to the realization that the reason that most fertilizers have lower amounts of ammonium sulfate is that it is more expensive than urea. Most retail fertilizers use urea as their primary source of nitrogen for economic reasons. Urea contains the highest percentage of nitrogen (47%) of any solid nitrogen containing chemical. It is cheap, easy to produce and

ABOVE LEFT Two specimens of *Ariocarpus fissuratus* prior to treatment with NH_4. **ABOVE RIGHT** The same two plants one year after treatment with NH_4.

transport. For commercial balanced fertilizers the only way to get the nitrogen content above 20% is through the use of urea.

N 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

Commercial nitrogen costs JR Johnson (10/2009)

Urea needs bacteria in the soil to break it down to a form that plants can use. For plants in soil that stays damp all the time, such as houseplants, urea nitrogen is fine. For cactus and succulent culture in pots where the soil dries out, this nitrogen does not become available to the plant roots. This is generally accomplished with the enzyme, urease, generated by bacteria. These bacteria are not found in desert soils or epiphytic media such as for orchids.

(Bacterial Urease)

$$NH_2CONH_2 + H_2O \rightarrow 2(NH_3) + CO_2$$

The urea either evaporates or is washed out of the pot with each watering. Urea is an unsatisfactory source of nitrogen for cacti and other xerophytic plants.

Nitrate — It has been advised that nitrate nitrogen is a preferable fertilizer for xerophytic plants[2]. However, the literature suggests that ammonium is much more readily absorbed especially for CAM plants [3,4,5]. There appears to be a significant preference in plants for absorption and assimilation of ammonium rather than nitrate. The relative rate of ammonium uptake and assimilation appears to be at least ten fold greater than the rate for nitrate uptake.

Formulations may vary depending upon where you live and what is available for fertilizer. We are advocating ammonium sulfate in conjunction with a balanced fertilizer and the constant application of fertilizer throughout the growing season. Keep in mind that the water should have its pH corrected to about 5.5.

High humus soils — More and more cities are selling the leaves and branches and green waste to companies that make potting mix. In California in most areas it is now illegal to burn your yard waste and so it is collected at a cost to the people and then sold to companies that make potting mix. Those towns that do not sell it, use it themselves.

Lumber mills that used to burn all their waste now sell it. Much of it goes into potting mix. When that waste is breaking down in the potting mix, it is removing nitrogen from the soil. So, the plants are being deprived of much needed nitrogen, that is unless it is replaced. For soils with high humus content containing materials such as "potting soil," sphagnum moss, coir, peat, and similar products, we suggest the following amounts for 114 li (30 gallons):

Material	CC	Tbsp.
20-20-20	60	4
Ammonium sulfate	120	8

Formulation for high humus soils

This is about 50 ppm N, P, and K for the mineral soils. For the high humus, potting mix soils, the amounts are 200 ppm N and 100 ppm P and K.

For a urea free mix, the amounts in 30 gallons of water should be.

	wt %	N	P	K
Schultz 10-54-10	15.0%	1.5%	8.1%	1.5%
potassium sulfate	15.0%	0.0%	0.0%	7.5%
ammonium sulfate	70.0%	14.7%	0.0%	0.0%
	100.0%			
Total amount in CC	130			
Total amount in tbsp	9			
	PPM in 114 li (30 gal)	190	95	105

Urea free formulation for high humus soils

ABOVE LEFT *Coryphantha elephantidens* near the beginning of treatment with NH_4.
ABOVE RIGHT The same plant five months after treatment with NH_4.

Highly mineral soils — These formulations will suit mineral soils such as ones made up of limestone, pumice, perlite and decomposed granite (no humus material). It will also contain the needed micro-nutrients. For highly mineral soils, we suggest for 30 gallons of water:

Material	CC	Tbsp.
20-20-20	30	2
Ammonium sulfate	30	2

Formulation for high mineral soils

The 20-20-20 fertilizer may contain large amounts of urea as its nitrogen source and this will be washed out of your soil..

If you wish to have a urea and nitrate free fertilizer, here is an example of what you can readily do. 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 ammonium phosphate. But these do contain the micro-elements. Potassium sulfate (K_2SO_4) needs to be added along with the ammonium sulfate in order to attain a balanced formula.

	wt %	N	P	K
Schultz 10-54-10	25.0%	10%	54.0%	10.0%
potassium sulfate	25.0%	0.0%	0.0%	50.0%
ammonium sulfate	50.0%	21.0%	0	0
	100.0%			
Total amount in CC	50			
Total amount in tbsp	3.5			
	PPM in 114li (30 gal)	50	52	58

Urea free formulation for high mineral soils

Application — The best way to apply is through your watering system. We have described watering systems in our previous article. For larger operations we would suggest the use of a Dosatron®. These run in the $400 range. For smaller systems a tank (garbage can) with a sump pump can be put in place for less than $100.

A Syphonject® system can also work. This will be less than $25. However we must warn that the dilution rate is heavily dependent on the back pressure. Thus your nozzle, hose size, flow rate, and hose length are critical factors that must be taken into account whenever they are changed.

If you are hand watering your plants by dip and pour from a bucket then you could use the cheaper pellitized form of ammonium sulfate. However, it is a good idea for watering systems to obtain the sprayable type. This material is used as an adjuvant for spraying Roundup® type chemicals. The sprayable type is totally soluble. There is a time release form and the cheaper pellitized form, both of which are not totally soluble and will clog up your nozzles. We have also seen several other commercial fertilizers with this problem. Make sure that your fertilizer is totally soluble and "Sprayable." Do not use the time release form of ammonium sulfate.

When you are compounding these solid materials, 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.

pH considerations — By and large most municipal water supplies are adjusted to a higher pH sometimes >8.0 and many wells also have high pH water. The high pH puts a strain on the plant roots and absorption of nutrients is prevented. This discussion is covered in our previous article[1]. The elevated pH in water supplies is due to the presence of bicarbonate.

Ammonium toxicity — There is much in the literature regarding the toxicity of too much ammonium to some plants[6]. It would seem surprising in light of the fact that in order for nitrogen to get into the plant it must be converted to ammonium. This uptake of ammonium is known to cause a pH drop close to the root and this is the presumed reason for ammonium toxicity. So the rapid absorption of ammonium becomes too much of a good thing for the plant.

NH4+ ----> (Plant N) + H+(acid) near roots

Plants have different reactions to ammonium. The following families are known to be sensitive: Solanaceae, Cucurbitaceae, Asteraceae, Fabaceae, Chenopodiaceae, Brassicaceae, Salicaceae, Rosaceae, Euphorbiaceae, and Urticaceae. The following plants are known not to be sensitive: Alliaceae, Ericaceae, Pinaceae, Fagaceae, Cyperaceae, Proteaceae, Taxaceae, and Myrtaceae. These plant families in general are tolerant of very low pH (<5.0). The authors suggest that the symptoms can be alleviated by use of buffered water and high levels of potassium.

However, we have used the same ammonium type of application on our tomatoes, peppers, eggplants and squash as we have with our succulents with wonderful results. These are all on the sensitive list. Perhaps what helps is that we are constantly applying a balanced fertilizer. Dropping the pH below 5.0 seems to affect members of Rosaceae (Potentilla), Impatiens, and Oxalis, a weed among our plants. Also going to a pH of 5.5 seems to correct this problem. At no time have we had any problems with Cactaceae.

What to expect from your plants – Our correspondents have first switched to a low pH regimen and subsequently have added ammonium sulfate nitrogen. The differences they see are very illustrative, since one of the most important issues is the initial quality of the water. Most of our correspondents had alkalinity (bicarbonate) levels of about 1 to 2 meq/li. They report that the effect of the 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.

However, 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" 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 mealybug 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."

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."

"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

ABOVE LEFT *Notocactus uebelmannianus* after regimen of NH_4.
ABOVE RIGHT The same plant prior to any applied NH_4.

how everything is really moving. Also the acidified water works wonders for seed germination."

The final results for everyone have been similar but it definitely depends upon where you start. Low pH and ammonium sulfate are definitely very good for the plants. But, don't think that you ought to do one without doing the other.

Conclusions — 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.

Excess nitrogen – There are several sources that claim excess nitrogen is harmful to cacti and succulents. Lush, spongy growth, higher susceptibility to mealybug and spider mite attack, poor over-wintering, poor flowering, and susceptibility to rot are the pronouncements. However, we are not exactly aware how much is too much nor have we seen it spelled out. We are not sure of where they come up with these statements. Buxbaum's text on nitrogen is typical: "For the so-called "plant-fertilizers" of commerce nearly always contain a lot of nitrogen, which leads to lush growth in cacti."[7,8,9]

Many of the other statements regarding nitrogen sources are simply erroneous, Such as -- "Better formulas will have a good portion of their nitrogen derived from urea. Urea is nitrate nitrogen that all plant connoisseurs should demand"2.

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