Fertilizing and Automatic Feeding

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Plants require water, light, carbon dioxide in substantial amounts, a place to put their roots, and some additional nutrients, typically taken up through the roots with the water. So-called major nutrients are nitrogen, phosphorus and potassium. The amounts of these contained in fertilizers are represented on the label as relative percentages, listed as N - P – K, for nitrogen, phosphorus, and kalium (Latin for potassium). Minor nutrients, necessary in smaller or even trace amounts for plant survival, include iron, magnesium, calcium, copper and a few others. They may not be in some fertilizers. The label will tell.

Especially in artificial soil mixes, our plants will require supplemental fertilization. Most bagged 'cactus mix' and home-made combinations intended for succulents contain things such as bagged potting soil (which is mostly sawdust—"forest byproducts"), coir, peat, sand, pumice and perlite. Such mixes lack almost all minerals and nitrogen. Plants may survive in such mixes for a while but will not grow and bloom.

House plants are even worse off; growing in nothing but standard bagged potting soils, they receive no nutrients of any kind unless Lady or Lord Bountiful feeds them regularly. This is why so many house plants wither, yellow and dwindle away within a few months of purchase.

I will talk mainly about desert plants growing in the desert. Other plants have other nutrition requirements; that would be another article.

Nitrogen

Plants use nitrogen to build amino acids. Amino acids are then strung together like beads to form proteins. Proteins serve many functions. Some serve as chemical catalysts, allowing the plant to make all its other chemicals; some assist in trapping sunlight to form sugar from carbon dioxide; some string the sugars together end to end one way to form starch, and another way (which we can't digest) to form cellulose, the major structural material of plants.

Nitrogen constitutes 70% of our atmosphere. It exists in the form of an invisible gas consisting of two nitrogen atoms bound together into one very stable molecule, N_2. But plants can take up nitrogen only in the form of nitrate, which is one nitrogen atom bound to three oxygen atoms, and which is chemically unstable in water solutions.

Plants cannot split atmospheric nitrogen to form nitrate; only certain bacteria, some fungi and lightning are able to do this. Normally, these nitrogen-fixing bacteria perform this trick in the soil, and plants may take up the excess nitrates. The legume family (Fabaceae) has learned to house nitrogen-fixing bacteria in small root nodules. This is why so many desert trees are legumes: desert soils are very poor in nitrogen, and the

guest bacteria provide food for the host. Inoculent for bean seeds consists of spores of these bacteria. I inoculate all seeds I sow in the bean family, including Acacia, Delonix, and Erythrina, as well as garden beans and sweet peas.

Other soil bacteria decompose proteins in the soil to nitrates. American Indians discovered this; they taught the pilgrims to put a fish in a hole, backfill, and then plant three kernels of corn over the fish. All our succulent plants benefit from supplemental nitrogen, and plants in non-soil mixes require it or they will not grow.

Phosphorus and Potassium

Plants use phosphorus to make adenosine triphosphate, which plants (and all other living things) use as an energy source for chemical reactions. Soil phosphorus exists mostly in the form of phosphates in combination with calcium or sodium. Phosphates tend to be very insoluble, accumulating in soils over the years. Desert soils are extremely rich in phosphates, and our plants in the ground don't need any extra. Plants in low-nutrient mixes need it, though.

Potassium is found in relatively high amounts in the sap or blood of all living things. It is needed for keeping cells alive, and for proper functioning of many enzymes. Our desert soils contain plenty of potassium, but soilless mixes don't.

Iron and magnesium

Plants make chlorophyll (the protein enzyme they use to trap sunlight) using for tools enzymes containing iron. Each molecule of chlorophyll itself contains one atom of magnesium. So, deficiencies of either of these minerals will lead to plants without adequate chlorophyll—they turn yellow, which we call chlorosis. Desert soils contain plenty of both minerals, but our soil acidity is low, and this inhibits uptake of these minerals into plants' roots. Warm weather and overwatering worsen the situation. This is why many exotic landscape plants turn yellow in the heat without either lots of supplemental iron or attempts to make soil more acid; we have to keep these exotics wet to keep them alive during periods of high heat, and we also need to give them extra iron or acidify their soil.

Calcium and Trace Minerals

Plants need calcium to form some woody structures like skeletons and spines, and it is a necessary cofactor for actions of most protein enzymes. Our desert soils are rich in calcium, so plants in the ground don't need extra. Copper is used as a cofactor for a small number of enzymes. We have plenty in our desert soils. Of interest, according to bromeliad specialty nursery Tropiflora™, the whole family Bromeliaceae, containing vase plants such as Aechmea, pineapples (*Ananas comosus*), Dyckia, Hechtia and Tillandsia, is very sensitive to copper, and it is best not to use copper-containing fertilizer on these plants.

What Product to Use

So, the question is: how to feed our succulent plants?

Controlled-release fertilizers, such as Osmocote™ or ammonium phosphate, seem attractive. They promise three, four or even nine months of slow-release feeding if mixed into potting soils. Unfortunately, these results are for temperatures in the 70s to 80s. Nitrogen-containing compounds not taken up by plants are decomposed by soil bacteria to molecular nitrogen, N_2. The hotter it is, the faster the bacteria chop up the nitrogen compounds. With temperatures over 90, controlled-release fertilizers actually provide nitrogen to plants for only a few days to weeks. I have concluded they are an expensive waste of time for desert gardeners.

Dry, quick release fertilizers can be sprinkled on the soil or potting mix, then watered in. There are "complete" fertilizers available, containing major and minor nutrients, and dry fertilizers containing nitrogen compounds only, such as ammonium sulfate, calcium nitrate, ammonium nitrate and urea.

The problem with the scatter and water method of fertilizing is that it is too easy to over-fertilize and burn plants' roots, leading to a sick or dead plant.

Liquid fertilizers are simpler to use; just mix and water. Most are sold as powders to be dissolved in water. There are "complete" liquid fertilizers, such as MiracleGro™ and Peters™; one can also dissolve ammonium sulfate in water. Most people use somewhere between ½ teaspoon to 1 tablespoon of any of these per gallon of water when fertilizing their plants. It is harder to burn plants accidentally with mixed liquid fertilizers, since the gardener controls the concentration in the water.

I have concluded watering with liquid fertilizer is the best way to fertilize my plants. I grow my container plants in desert soil, so I only need to provide nitrogen. Instead of "complete" fertilizers, I use ammonium sulfate, which contains nitrogen in the form of ammonia.

Plants in soilless mixes of coir and pumice or the like require "complete" fertilizers on a regular basis or they will not grow.

What Kind of Nitrogen to feed

Soil bacteria break down ammonia dissolved in water to nitrate, which can be taken up by plants. This happens faster at warmer temperatures, and slower at cooler temperatures. Under about 60 degrees it happens very slowly, so ammonium sulfate is not considered a good winter fertilizer. However, when it is above 90 degrees, almost all the ammonia will be converted to nitrate very rapidly, and be available for uptake by plants. Nitrate unused by plants, in turn, will then be converted to nitrogen very rapidly Most rapid-acting nitrogen fertilizers are essentially gone within an hour in the summer.

One may read ammonium sulfate is poor fertilizer, breaking down too quickly, and longer-lasting nitrogen sources such as urea are better. This is good advice for people living where summer temperatures hover in the 70s or 80s. In our high summer temperatures, though, it is not correct. Any quick-release nitrogen fertilizer used here in

the summer will be metabolized to air within just a few hours. Use whatever is cheapest, which is ammonium sulfate.

Because of rapid metabolism at high temperatures, it is a waste of money to buy calcium nitrate or ammonium nitrate fertilizer for summer use; ammonium sulfate works just fine. However, in cooler weather, calcium nitrate or ammonium nitrate may be a better choice, since nitrate is already available without intervention of winter–sluggish bacteria. These fertilizers are twice or more as expensive as ammonium sulfate. Our cacti don't need feeding in cooler weather, but winter-growers such as some Aloe, Haworthia and mesembs like it a lot.

Blood meal or dead animals do break down more slowly in the soil, releasing nitrates, but they also attract animals who want to dig up your plants to get the tasty treats. I recall reading a 150-year-old English gardener's book which recommends wrapping a dead rat in a cloth and burying it in a large decorative container to hold a parlor palm. I don't recommend this.

Cacti Must Be Fertilized

And, one may read cacti and other succulents shouldn't be fertilized! This is silly. Plants in the wild have soils rich in minerals, and in many desert areas blue-green algae live on the surface, converting atmospheric nitrogen to nitrates. If you have hiked in the desert you may have seen, in areas where water would collect after a good rain, thin black or dark-green peeling layers of something or other. This is a blue-green algae called Nostoc. It has been shown this symbiosis occurs in Namibia; it would be a great research study for a student here. Plants in soilless mixes don't get any nutrients at all. They must be fertilized to grow.

Fertilize Cacti in the Evening

Recall cacti and other succulents using C4 metabolism open their pores and take in water at night only. Fertilizing on a summer morning is mostly a waste of time; the plant's pores are closed, and won't be open until dark, by which time the nitrogen in the fertilizer will have been converted to air. Fertilize in the late afternoon or evening to be sure the plants clean their plates.

How Often to Feed

Ideally one would provide a very dilute fertilizer solution at each watering, with occasional fresh waterings to rinse out accumulated salts. This way the plant will have nutrients available whenever it decides to grow, and equates to people eating frequent light and healthy snacks during the day. The way most people water, giving a full-strength blast every 2-8 weeks or when they remember, is like a person going on a fast, then breaking down and bringing on five pounds of Sees Candies™ at one sitting.

Fertilizer Injectors

But, somebody has to mix the fertilizer, and it has to be mixed just before use, or hot temperatures will set to work on the ammonium and nitrate. I have watered hundreds of plants at a time with liquid fertilizer I mixed in one gallon containers. What a pain! One

can also mix a large quantity at once, perhaps in a barrel or large plastic container. Then one must dip out pitchers of fertilizer water. There must be an easier way?

There is. One can buy fertilizer injectors at reasonable prices. These work on a siphon principle; the injector uses water flow to siphon measured amounts of concentrated fertilizer solution from a bucket or barrel, and puts it in the main water flow at a predetermined dilution. If attached to a garden hose, the water flowing from the end of the hose contains fertilizer at the chosen concentration. Work is greatly reduced; one must only mix the concentrate in the bucket or barrel.

Simple, Slightly More Work

An inexpensive and vey well-made injector is the Dramm Syphon Ject ™ (www.Dramm.com; less than $20 at many nurseries). It is a brass fitting with a side nipple onto which fits a rubber tube weighted at one end with a filter (Figure 1). The fitting screws onto a standard hose bib and a standard garden hose, then screws onto the injector (Figure 2). The rubber tube slips on the nipple and the filter end is dropped in a bucket containing concentrated fertilizer solution (Figure 3). When the hose is running, the injector siphons concentrate from the bucket and yields a fixed dilution ratio of 1:16. One gallon of concentrate will be diluted to 16 gallons of fertilizer solution. This is governed by the size of the internal siphon channel and cannot be changed.

This injector only works at relatively high water flows. The water flow needed is really too high for plants in smaller pots unless one uses a good watering wand to break the stream. One can also use the hose to fill a watering can or another barrel and avoid the trouble of picking up a measuring spoon with wet hands, then dipping into the fertilizer container.

Sixteen seems a strange number to pick for dilution ratio until one realizes there are 16 tablespoons per cup. Peters ™ and MiracleGro ™ suggest using one tablespoon per gallon of water for fertilizing plants. So, to yield a concentration of one tablespoon per gallon coming out of the hose, each gallon in the concentrate bucket should contain 16 tablespoons (one cup) of fertilizer powder. If you prefer weaker fertilizer, calculate accordingly. For example, if one prefers ½ teaspoon per gallon, into the bucket one would put 16 times ½ teaspoon or eight teaspoons per gallon of concentrate. A five-gallon bucket of concentrate will yield 80 gallons of fertilizer solution.

The system must be rinsed with clean water and dried after each use to prevent corrosion. Simply put the rubber siphon in a bucket of clean water, turn on the hose and run a gallon or so through the injector. Remove the brass fitting and rinse it thoroughly. Let both pieces dry in the shade. The rubber tubing must be stored out of the sun, preferably in the house, since high temperatures age rubber rapidly. When the tubing finally wears out, it can be replaced at any hardware store. Take the old piece and brass injector along to ensure getting the proper replacement. The Dramm Syphon Ject ™ should last many years with proper cleaning.

Less Simple, More Automatic

The next step up is installing an inline injector for your irrigation system. Rodney Anderson, who grows wonderful palms and cycads, began using this system years ago. Monte Crawford in our club inspected Rodney's system and installed one of his own. They taught me what they do. They evaluated all the products on the market and found the best one: the Chemilizer Chemical Injector™ (www.chemilizer.com, or you can call them in Florida for a brochure: 727-518-1665). There is an enormous amount of information on their Web site.

The Chemilizer™ consists of a pitcher-sized blue water pump (item CH9000-210, $280, see Figure 4), and a juice-glass-sized white chemical pump and cap (items FG9210-V and FG9936-V, $55 for both, see Figure 5). The water pump is plumbed into the incoming irrigation line. The chemical pump is inserted at the bottom of the water pump. A length of tubing is inserted onto a nipple on the chemical pump, and the other end is placed in a barrel or bucket of fertilizer concentrate. Be careful; it is easy to break off the nipple when installing the pump. I recommend buying a spare cap or two in case this happens.

When water is running, the flow through the water pump activates the chemical pump, which sucks concentrate from the barrel and puts it in the water main just downstream from the water pump. A great advantage of this system is that it provides a constant dilution at any reasonable flow rate, unlike the Syphon Ject™, which must be run at high flow.

This system is plumbed into an irrigation line. It is not hard to do yourself, though since I'm lazy, I paid somebody else to do it. It works fine with standard PVC pipe. A typical plumbing diagram is here: (Figure 6).

It could also be used as a portable system, mounted on a rolling cart; attached a female brass hose fitting on the inlet side, and a male brass hose fitting on the outlet side. Use a short hose to attach to a hose bib, and attach the watering hose to the pump outlet.

The company developed this system for industrial chemicals, and only later realized it could be plumbed into irrigation systems to provide continuous feeding. Many applications are on their Web site. I have mine plumbed into the intake water pipe to nine of my irrigation lines. (I have one drip line for patio pots, three soaker hose lines for my orchard, and one drip line each for landscape cacti, landscape succulents, landscape shrubs, landscape cycads, and my rose bed.) There is a bypass valve system so I can exclude the pump from the system and irrigate with fresh water. I can use different fertilizers for different lines by switching the chemical pump intake tube from one concentrate barrel to another. I use pH adjusted, balanced fertilizer for my cycads and ammonium sulfate for the other lines.

Chemilizer™ makes two kinds of pump systems: one provides a fixed dilution, which depends on the chemical pump inserted into the water pump; the other can provide variable dilutions, which require some calculations and some work. The variable pump is also almost twice as expensive. I bought the 1:100 fixed-dilution chemical pump,

meaning I mix the concentrate 100 times as strong as what I want the plants to get. I only have to run the calculations once and then I know how much fertilizer to add to my barrel. I add two cups (32 tablespoons, 96 teaspoons) of dry ammonium sulfate per gallon of water in my concentrate barrel to yield just under one teaspoon ammonium sulfate per gallon of watering solution.

One may also plumb a hose bib downstream from the Chemilizer™. Then any water from that hose bib—or any bucket filled there—will contain fertilizer. Don't drink from that hose bib!

Acidifying Water
There was quite a discussion in our August meeting about putting vinegar in the water. Why?

Our desert soils are quite alkaline. This is because rain falls and dissolves minerals. As the rain moved downhill it brings with it extra minerals, and then the water evaporates near the soil surface in flat areas. Rains are relatively brief so desert soils tend not to get wet very far below the surface. Over many years, all these imported minerals become concentrated near the surface of the soil since they are never leached down and away. One can see the same thing around a drip irrigation emitter—at the margin of the wet soil zone a white mineral layer builds up over time. These minerals tend to be things like calcium and magnesium phosphates and carbonates, which are quite insoluble. They render the soil alkaline. Excessive concentration of these minerals over many years forms caliche.

The Infamous Crime Against Nature
Most desert plants in the ground do fine in alkaline soils, but it is highly unnatural to grow plants in containers. Every watering, water left in the pot will dry, leaving another load of dissolved minerals. One sees this as the white mineral buildup on clay pots. This mineral load dissolves clay and ceramic pots. Think what it does to your plant's roots. From a plant's perspective, pots are dungeons, torture chambers.

Hospitality for Foreign Guests
Exotic plants from non-desert areas, rarely appreciate alkaline soils. Many of our favorite caudiciform succulents are not from desert areas, rather from summer-wet, winter-dry areas. They appreciate less alkaline soil, whether in the ground or in a container. Going a little farther afield, many common landscape plants also do better in less alkaline soils; things like roses, vegetables, jasmine, honeysuckle, and Cycads will grow fine in our alkaline soils, but if irrigated with more acid water, they grow spectacularly and look much bluer.

The simples but slowest way to decrease alkalinity in the soil is to maintain a 6-inch layer of organic mulch at all times. Soil bacteria will take care of the rest if you don't kill them with RoundUp™. If you have any kind of fruit trees or rose beds, you absolutely must do this for best results here in the desert. But mulching doesn't work in a four-inch clay pot.

Eliminate Container Salt Buildup
For container plants, the most effective way to decrease alkalinity is to add a tiny bit of acid to your water. You must not guess; desert plants don't like soil that is too acid.

Note that using ammonium sulfate for fertilizer helps acidify the soil. Once the ammonium is gone, the sulfate (which is part of sulfuric acid) helps decrease the alkalinity: another reason to use ammonium sulfate.

Be Careful!
Inorganic acids such as hydrochloric acid (also called muriatic acid, and used in swimming pools) and sulfuric acid can be used, but they are dangerous. Don't use these unless you have been trained in handling them and you don't mind holes burned in your clothing. Remember what parts of you are situated right at the level where you tend to carry a bucket or spill things, protected only by thin cotton cloth. And always use the proper skin and eye protection. My lap partner in general chemistry splattered muriatic acid on the front of his cotton polo shirt. The shirt (an expensive Izod, back when that was tres chic) disintegrated and fell off him. He had blisters across his chest and abdomen. Fortunately he was wearing goggles and lab gloves.

Organic acids such as acetic acid work well, too. Vinegar is a dilute solution of acetic acid which most people consider safer to handle than inorganic acids. Be careful and measure! Undiluted vinegar can be sprayed on weeds to kill them. Vinegar contains carbon, and can be used as a nutrient by many plants and bacteria. In humid climates, adding vinegar to the water for plants in pots leads to a prodigious growth of moss on the pot and soil; in our low-humidity, we don't have to worry about this.

Whichever acid one chooses, guesstimating how much to add might lead to harming plants. One must measure the acidity of the water and add the proper amount of acid to correct it just right. Acidity may be measured with pH paper or a swimming pool pH measuring system. pH is a measurement of acidity/alkalinity using a scale from 1 to 14—the higher the pH, the higher the alkalinity; the lower the pH, the higher the acidity. The inside of your stomach is pH 1 (unless you take the little purple pill). A concentrated solution of lye in water is pH 14. Neutral—not acid, not alkaline—is pH 7. Our desert soils tend to be around pH 8 or higher.

How much to Use?
Before acidifying water, one must know the starting pH. First use pH paper or a swimming pool test kit and find the pH of tap water. Then put a quart of tap water in a larger, non-metal container (metal interacts with the acid you will add). Add a few drops of acid, stir well with a glass or plastic implement, and check the pH again. Keep a careful record of how much acid is added. Continue this routine of adding a few drops of acid—stirring—checking the pH until the pH is in the range 6.5 – 7.0. This is called an acid titration.

To double check, start with a quart of fresh water. Add the entire amount of acid you calculated and stir. Check the pH. It should be the same number as before. Multiply by

four to find the amount of acid needed to bring one gallon of tap water to the desired pH. If using a bucket and Dramm Syphon Ject™, add 16 times this amount to each gallon in the concentrate bucket.

Fertilizer water can also be acidified; but the fertilizer itself will change the pH of the solution, so do not simply add the amount of acid for tap water to a fertilizer solution. Rather, do an acid titration starting with the fertilizer solution.

Take a quart of fertilizer solution of the concentration to be used. Check the pH, add acid drop by drop, and check pH frequently to find how much acid to add to a fertilizer solution. Record the number. For injector watering with acidified fertilizer solution, add the dry fertilizer to the empty bucket, then half the water, then the acid, then the rest of the water. Stir. Drop in your suction tubing and go to town. Remember to rinse your injector when done.

Municipal water tends to be very constant in terms of alkalinity. So, once you figure out an acid titration, you won't need to repeat it.

I don't acidify the water for my landscape plants, except for the cycads. But I do use my Syphon Ject™ to mix ammonium sulfate and vinegar for my potted plants.

Try it and see.

Cutlines for photos:

Figure 1: Brass injector and rubber aspirator line

(the next 4 are on the same page)
Figure 2 (Top): Injector attached to hose bib; aspirator attached to injector.
Figure 3 (Left): Aspirator line to bucket.
Figure 4 (Below): Chemilizer™ water pump. White chemical pump visible at bottom.
Figure 5 (Bottom): Chemilizer™ chemical pump.

Figure 6: Injector plumbing diagram.