What Do Orchids Eat?

[1–2] *Paphiopedilum tonsum* 'Robin's Jungle Ghost', HCC/AOS, which was purchased as a single-growth plant in 2009, flowered in 2010 [1]. The progression of plant size, color, substance and flowering success once the new fertilizing regime was implemented in 2011 is evident [2]. Grower all plants shown: Rick Lockwood.

I BEGAN MY ORCHID EXPERIENCES in earnest in 2001. Most of my culture practices have been developed from the experiences and advice from more experienced growers. I tempered and refined these practices with my general knowledge of biology (especially ecology), which I had used to develop culture protocols for things like tropical fish and poison dart frogs. In 1995, I began a career as an environmental toxicologist that focused my attentions on the internal mechanisms causing toxicity in aquatic organisms. I have been focused for the last six or so years on how the major ions (salts) cause imbalances and toxicity in both fresh- and saltwater organisms and plants. The major ions influential in aquatic toxicity are the same critical ions for all plants, including orchids. The major ions are calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), sulfate (SO_4), bicarbonate (HCO_3) and chloride (Cl). Together with nitrogen (N) and phosphate (PO_4), these form the majority of what plants use as "nutrients."

WHAT'S THE PROBLEM? I've focused primarily on slipper orchids, species of *Paphiopedilum* and *Phragmipedium*, but I also enjoy growing species of *Phalaenopsis* and *Bulbophyllum*. My first five or so years of orchid growing focused primarily on the physical aspects of orchid culture: getting down the light, temperature and humidity requirements of my plants. This is definitely the foundation of growing good orchids, and probably accounts for at least 75 percent of the success I've enjoyed at this point. But I've been plagued with regular chronic problems, and observed several inconsistencies of success and failure among different growers, that I now attribute to nutrition problems. Furthermore, in the case of orchids, nutrition cannot be completely separated from potting mix (Trelka et al. 2010) and water chemistry factors.

The laundry list of my problems and cultural inconsistencies include:

♦ I could not grow phalaenopsis in pots without killing them, but many growers have excellent results in either standard pot or semihydro culture (where some roots may be continuously submerged in water without rotting). In general, I had much more success with plants in baskets or on mounts than in any system of pots and potting mixes.

♦ Plant leaves turning purple.

♦ "Easy" *Paphiopedilum* species like *Paphiopedilum sukhakulii* and *Paphiopedilum callosum* have been extremely difficult for me to keep alive for more than a few years, but bloom like crazy all the way to the end.

♦ Multifloral *Paphiopedilum* species only did well when only very small pots were used relative to the size of the plant. For instance, a 2-inch (5-cm) pot for a plant with a 24-inch (60-cm) leafspan. Increasing pot size generally precipitated root rot.

♦ Poor root growth, short-term good root growth and root rot problems in bark or coconut husk chips (CHC) mixes. Short-term transfer to sphagnum would generally revive root growth.

♦ I could use CHC mixes with multifloral paphiopedilums, but not long term with other *Paphiopedilum* species.

♦ Use of calcium-supplementing materials such as oyster shell or limestone did not

Are Your Orchids Addicted to Potassium?

TEXT AND PHOTOGRAPHS BY RICK LOCKWOOD

offer long-term support of paphiopedilums, but these materials are often a mainstay of other growers' potting mixes.

♦ Plants — mostly slipper orchids, but some other large and fast-growing orchids, such as a *Phalaenopsis schilleriana* and a *Oncostele* Wildcat (Rustic Bridge × *Onc*. Crowborough, 1965), formerly a *Colmanara* — would grow quickly for a few seasons, followed by slow growth, stunted new growth and susceptibility to disease until demise.

♦ Seedlings out of flask initially grew very well up to a year, followed by lack of growth and susceptibility to disease until demise.

♦ Some species were highly susceptible to *Erwinia* rots.

♦ Leaf-tip burn in phragmipediums.

Although these were the problems I was experiencing, I found that these were common for many fellow growers. Usually the verdict was, "Oh, species XYZ is known to be a tough one." Then there are the general knowledge culture inconsistencies:

♦ "Rots occur due to watering at night." But many orchid species get rained on at night or for days on end without rotting in the wild.

♦ *Paphiopedilum* species in subgenus *Brachypetalum* are "sensitive to salts," but five of the six primary *Brachypetalum* species are found so close to the ocean that they encounter salty ocean spray on a daily basis. Two of the most popular are *Paphiopedilum niveum* and *Paphiopedilum leucochilum*

♦ "Calcareous orchid species require calcium in the potting mix." But many growers are successful with nonsupplemented bark, CHC or inert mixes.

Using my research background I started intensifying my observation of other successful orchid growers' practices, and reviewing research from the commercial, nonorchid agricultural community to build a larger body of comparative data to look for patterns in success and failure.

One key source of information I discovered around 2004 came from Bob and Lynn Wellenstein's AnTec Lab reading room, with the documents "Mineral Nutrition for Slipper Orchid Growers" (http://www.ladyslipper.com/minnut.htm; 2000), and "Use of Coconut Husk Chips for Potting Medium"

(http://www.ladyslipper.com/coco3.htm; 2004). Over the years, several articles in the reading room have been influential for my program. Two of the main points to take home from these two articles is the competitive, or antagonistic, interactions among potassium, calcium and magnesium, and the ion exchange capacity of coconut husk favoring the monovalent cations (sodium and potassium) in favor of the divalent cations (magnesium and calcium). At the time, however, I largely discounted the notion of antagonistic or overdose interaction, because the predominant wisdom at the time was "orchids take what they need as you pour it on them, and leave what they don't need." Fertilizer components were considered beneficial nutrients for feeding plants by horticulturists rather than toxic inorganic chemical salts used for dosing plants, which a toxicologist would relate to.

Please note, however, that the ratios of major nutrient ions listed in the Wellenstein article on mineral nutrition for slippers are similar to the Michigan State Universty (MSU) fertilizer mix, and the ratio of nitrogen to potassium is similar to just about all "balanced" commercial fertilizer mixes. (I recently came across a Scott's lawn care fertilizer with a very low phosphorus and potassium ratio to nitrogen.) Furthermore, it was difficult to get anyone to talk about much besides the ratio of nitrogen-phosphorus-potassium (N-P-K) of a mix. Calcium and magnesium were only ascribed a limited role.

With continued culture shortcomings after attempts to refine my fertilizing and potting practices based on my perceptions of what other successful growers were doing, I started experimenting with bone meal (calcium phosphate) and, later, Epsom salt (magnesium sulfate). These were supplementing practices that have been used for centuries in the general horticultural community, but had fallen out of favor in the orchid-growing community in favor of the more targeted MSU approach. Some short-term gains were quickly noted after calcium phosphate addition, primarily in returning some plants with purple leaves back to green. Much greater positive changes throughout my collection were noted after Epsom salt additions. Pale green or yellowing plants turned dark green, and leaf length increased by over 20 percent in some plants. The new growths and roots were larger and more durable. The patterning of the mottled-leaved paphiopedilums became distinctive, and in general the leaves of paphiopedilums became tougher and glossier. I was getting closer, but still having problems with roots, seedlings and occasional *Erwinia* bouts with large plants. So I dug deeper into the general agriculture and rainforest ecology literature (Bruijnzeel 1991, Crowther 1987, Medina et al. 1994, Vitousek and Sanford 1986).

THE DATA From these sources I deduced the following generalizations:

♦ Plants in natural settings, regardless of species and habitat, have similar ratios of the primary elements. In priority, these are:

Table 1. Mineral-element concentrations (mg/gram) in mature and senesced leaves from epiphytes in Panama. Recreated from Zotz 2004 with the botanical names as originally published.

		Mature Live Leaves					Senesced Leaves				
Species	Family	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Anthurium brownii	Araceae	12.3	1.28	23.5	17.7	3.7	8.4	0.49	18.4	36.9	6.4
Anthurium clavigerum	Araceae	30.7	1.36	18.9	24.6	7.5	20.9	0.59	12.5	31.7	7.6
Anthurium friedrichsthalii	Araceae	13.0	1.32	32	39.4	7.5	7.7	0.61	25.3	41.4	7.6
Anthurium scandens	Araceae	7.5	0.47	15.1	21.8	9.4	5.5	0.27	5.3	19	7.5
Clusia uvitana	Clusiaceae	7.6	0.38	11.7	39.2	5.8	6.7	0.31	10.7	34.7	5.2
Peperonia macrostachya	Piperaceae	11.2	2.27	43	30.1	5.4	8.7	0.6	39.6	40.3	9.1
Aspasia principissa	Orchidaceae	14.6	0.73	20.7	19	1.1	8.4	0.32	19.3	20.1	0.7
Catasetum viridiflavum	Orchidaceae	10.8	0.58	17.4	20.7	6.3	6.7	0.09	11.4	16.7	4.8
Caularthron bilamellatum	Orchidaceae	12.7	0.61	29.1	15.2	3.2	7.8	0.09	16.9	7.1	2.1
Dimerandra emarginata	Orchidaceae	9.4	0.94	18.3	19.5	1.9	4.3	0.3	6.8	18.5	1.7
Encyclia chimborazoensis[1]	Orchidaceae	13.4	0.61	10	10.2	2.3	7.1	0.17	1.7	11.9	2.7
Epidendrum imantophyllum[2]	Orchidaceae	15.5	2.11	33.7	23.3	6.4	8.5	0.62	19.2	8.1	4.4
Epidendrum nocturnum	Orchidaceae	11.4	0.54	2.3	22.4	6.5	6.8	0.08	0.7	19.7	5.9
Epidendrum rigidum	Orchidaceae	11.3	0.51	2.6	26.4	9.4	6.8	0.07	1.8	15.5	8.8
Gongora quinquenervis	Orchidaceae	25.8	3.09	34.4	33	6.1	13.4	0.75	7.7	34.3	7.9
Maxillaria friedrichsthalii[3]	Orchidaceae	9.8	0.45	7.4	10.8	2.5	6.5	0.21	6.1	9.8	2.6
Oncidium ampliatum[4]	Orchidaceae	11.4	0.85	3.4	28.8	8.6	10.9	0.52	2.8	11.7	10.2
Polystachya foliosa	Orchidaceae	20.8	1.02	20.9	20.7	5.2	10.5	0.43	13.9	27.1	5.2
Sobralia suaveolens[5]	Orchidaceae	13.4	0.75	11.7	14.5	1.3	11.6	0.5	10.7	8.4	1.6
Trigonidium egertonianum	Orchidaceae	12.4	0.85	8.3	5.5	1.7	7.3	0.24	1.3	10.1	3.0
Species	Family	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Average (all species)		13.8	1.0	18.2	22.1	5.1	8.7	0.4	11.6	21.2	5.3
Average (all species/no ants)		12.6	0.7	12.6	20.1	4.8	8.3	0.3	8.7	19.9	5.0
Average (orchid species)		13.8	1.0	15.7	19.3	4.5	8.3	0.3	8.6	15.6	4.4
Average (nonorchid species)		13.7	1.2	24.0	28.8	6.6	9.7	0.5	18.6	34.0	7.2
Average (orchid species/w ants)		14.8	1.3	25.6	21.8	4.2	8.2	0.4	13.6	17.5	3.6
Average (orchid species/no ants)		13.2	0.7	9.7	17.6	4.3	8.4	0.3	6.5	14.9	4.5
Orchid % recycled (all orchids)							39.5	67.8	45.4	18.9	1.4
Orchid % recycled (all w/ants)							44.7	73.1	47.1	19.8	13.6
Orchid % recycled (all no ants)							35.9	59.7	33.2	15.2	-5.4

Nonorchid species data or combined orchid/nonorchid data.

Data from all orchids (ant and nonant associates).

Orchid only data segregated by association with ants.

Orchid only data segregated by no association with ants.

The plant with the highest K.

The following names are currently accepted by the World Checklist of Selected Plant Families. [1]*Prosthechea chimborazoensis*. [2]*Epidendrum flexuosum*. [3]*Rhetinantha friedrichsthalii*. [4]*Rossioglossum ampliatum*. [5]*Sobralia bletiae*.

[3–5] The plant habit of *Bulbophyllum cornutum* 'Robin's Purple Craze', AM/AOS, when it was awarded in 2007, with soft, droopy, pendulous leaves, which are sensitive to low humidity [3]. After it began a slow decline, the surviving pieces were transferred to a Hydrolog-like system where it continued to decline until the low-potassium nutrition program was started. Note that growths and leaves stand out almost perpendicular to the mount [4], showing off the flowers [5].

nitrogen > calcium > magnesium ≥ potassium > phosphorus > sodium. This includes an amazing array of plants from ocean kelp, river algae and sphagnum moss, to rainforest trees and shrubs.

♦ Free, bioavailable potassium is relatively rare in the environment, forcing plants to actively uptake or recycle this nutrient when available.

♦ Calcium and magnesium are relatively common in the soil and aquatic environment so plant uptake of these nutrients is more passive (relative to potassium uptake).

♦ Tropical orchids are primarily found in leaf litter, epiphytic on trees or lithophytic on cliffs or rocks. None of these habitats has large amounts of potassium relative to calcium and magnesium, and potassium is particularly rare in limestone lithophytic environments.

My specialty work in aquatic toxicology focusing on salt toxicity was also important to putting together the pieces of the puzzle. Because water flows downhill, knowing what is in the river, stream, creek or even ocean gives insight to what nutrition plants upstream in the trees or on cliff faces are accessing. The most obvious aspect of the aquatic toxicology of salt is that potassium is the most toxic element of the seven major ions, while calcium and sodium are the least toxic. Freshwater mussels, found worldwide, but globally imperiled in much of their present range, cannot handle much more than 10 to 20 parts per million (ppm) of potassium on a long-term basis, and 60 to 100 ppm will kill them in just a couple of days. The typical balanced fertilizer, applied at the rate of 100 to 200 ppm N will have just as much K, and is lethally toxic to this globally widespread aquatic organism. It is obvious that orchids in the wild do not experience weekly assaults of concentrated potassium. A typical stream, outside of human impacted areas where mussels are no longer found, will generally have 4 or fewer ppm of potassium. Rainwater rarely has any significant potassium, limestone is almost devoid of potassium and granitic feldspar is too insoluble to release significant amounts of potassium during a rain event. My house in Tennessee sits on a forested karst limestone ridge where native orchids can be found. A recent analysis of my well water showed 162 ppm calcium (Ca), 12 ppm magnesium (Mg), 3 ppm sodium (Na) and less than 1 ppm potassium (K). So where do orchids get their potassium?

Looking at Table 1 (from Zotz 2004) and Table 2 (from Hermansah et al. 2002) (see page 170), we can see that the amount of potassium (and phosphorus too, for that matter) in plants is significant, and considerably more abundant than what is available from the air, water or the local geology. The situation for nitrogen, calcium and magnesium is different with respect to the amount of these materials in the local environment. However, in order for the potassium to reach the levels found in plant tissues, it must constantly recycle and bioaccumulate through the litterfall and soil making process. The Zotz work in particular demonstrates the importance of nutrient recycle of rare elements in the Panamanian rainforest, and shows that epiphytic plants (including orchids) reabsorb/recycle about half of their potassium during leaf senescence. Phosphorus is recycled at a greater rate, but calcium and magnesium are recycled at low rates. A key factor I deduced from the Zotz work, but not mentioned in the text, is the relationship that ants have with some epiphytic plants and the nutritional role they play for these plants.

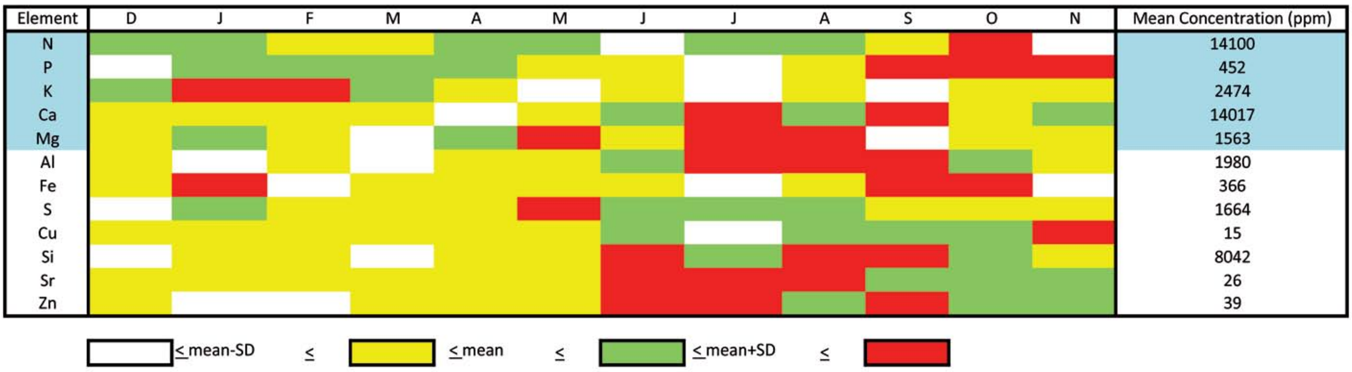
So noting that potassium is much rarer in the environment than in plant tissues, and also knowing that the MSU fertilizer is based on leaf tissue analysis, I started looking into plant physiology and cellular metabolism literature. Very little is written on wild orchids (or wild plants in general) with the bulk of literature based on studies with domesticated agricultural plants. I was able to summarize the following:

♦ Epiphytic plants are very efficient at uptaking and sequestering potassium (Winkler and Zotz 2010). Apparently this is also an energy requiring process. The uptake of potassium is like the "kids in the candy store" analogy. Wild epiphytic plants do not have the capacity to regulate the uptaking and storing of potassium in their tissues.

♦ Given the active transport of potassium in plants, bioavailable potassium will be readily taken up by plants in excess, which will then ultimately block the uptake of calcium and magnesium (antagonism). This will in turn reduce the uptake of phosphate (which is facilitated by the presence of calcium and magnesium in plant tissues; Shaibur et al. 2008).

♦ Plants that have incurred unfavorable tissue ratios of potassium/calcium/magnesium will have reduced growth and are

Table 2. Seasonal pattern of nutrient concentrations of litterfall from December1997–November 1998 in West Sumatra tropical rainforest. Table recreated from Hermansah et al. 2002.



susceptible to disease (Easterwood 2002).

♦ The regular use of high-potassium fertilizer is indicated for fast-growing plants that are completely harvested at the end of a single growing season, such as corn, wheat or rice. Slow growing perennial crops (such as fruit trees) need only intermittent potassium supplementation during the fastest annual vegetative growth phase, and when soil is depleted (Thompson 2011).

THE SOLUTION Armed with the above information, I needed a new fertilizing strategy for all of my orchids, and a new potting strategy for the paphiopedilums. I first compared the proportional ratios of the major ion content (N, P, K, Ca and Mg) of what I was using with what the wild plants contained in either live or senesced leaves.

♦ GreenCare MSU (pure water) 13-3-15-8-2 Orchidmix™ MSU 12-6-13-7-2

♦ Zotz (2004) average all species, live leaves, 14-1-18-22-5

♦ Zotz (2004) average encyclias, epidendrums and oncidiums only, senesced leaves, 8-0.2-2-15-7

♦ Zotz (2004) average non ant orchids, senesced leaves, 8-0.3-6.5-15-4.5

♦ Hermansah (2002) leaf litter, 14-0.4-2.4-14-2

♦ Naik and Barman (2007) live leaves, 4-1-9-24-13

Other leaf litter data are within the ranges of the ratios listed above, but some trends were obvious. Excluding the data from ant-fed plants, the amount of potassium is less than half the calcium and no more than equal the amount of magnesium. In leaf litter or senesced leaves the amount of potassium is less than the amount of nitrogen. Because the plants are recycling a certain amount of nutrients (mostly the N-P-K), I considered the leaf litter and senesced leaf data to represent what the plants were actually losing, and what they needed for replacement for either maintenance or growth. Furthermore, the orchids living in leaf litter accumulations on the forest floor (such as some of my favorite *Paphiopedilum* species) would be experiencing the nutrient concentrations found in the mixed leaf litter as their primary nutrient source. Thirdly, the paper on the uptake of potassium by epiphytes (Winkler and Zotz 2010) indicated that epiphytes would obtain sufficient potassium from very dilute sources, which I interpreted as natural surface water concentrations not toxic to aquatic life.

In a similar fashion to my work with freshwater mussels, I developed a new fertilizer mix by substituting available salts with different cationic makeup. My reduced potassium and increased calcium and magnesium program was initially accomplished by reducing the amount of MSU fertilizer by half, and adding equal parts of calcium nitrate and magnesium sulfate. This kept the nitrogen and phosphorous levels constant while drastically reducing potassium and increasing both the calcium and magnesium. Ultimately, I cut the total amount of fertilizing in half again so total nitrogen input is 30–50 ppm, only occasionally going back up to 100 ppm on warm sunny days. The expected nutrient ratios for this fertilizer mix were: 6-3-3-8-4 if applied at roughly 50 ppm nitrogen. Between weekly fertilization events, all irrigation water is supplemented with calcium and magnesium (primarily through the addition of my well water diluted 10:1 with reverse-osmosis [RO] water). As I noted in my research, growers utilizing surface or tap waters to mix up their fertilizer (as opposed to RO water, distilled water or rainwater), were less apt to experience the symptoms I discussed earlier. Also note that if MSU pure water formula is mixed in a medium-hard or hard surface water, then the resulting K:Ca:Mg ratios are similar to the species live leaf data as reported by Zotz (2004). Epsom salt is supplemented intermittently in regular irrigation water on warm, sunny days.

I began this program in spring 2011, but by December 2011, a collaboration of my fellow Slippertalk members, spearheaded by Ray Barkalow (First Rays), Doylestown, Pennsylvania, working with GreenCare, produced another formula we call "K-Lite." For a use rate of roughly 100 ppm nitrogen the nutrient ratio is 12-1-1-10-3 if added to RO water. Because I mix it at roughly 50 ppm nitrogen in soft water (which has additional Ca and Mg), my final mix is roughly equivalent to a 6-0.5-0.5-6-2 ratio. Using the mixture at 50 ppm, I'm still offering 4 ppm of potassium, which appears more than sufficient for my orchids. The K-Lite was made by GreenCare, who also mix the standard MSU formula. The K-Lite formula contains all the same trace metals as the standard MSU formula.

The majority of my paphiopedilums have been repotted into wooden slat baskets lined with New Zealand sphagnum moss. The sphagnum-lined baskets get coarse limestone chips (driveway grade gravel) in the root zone followed by more moss and coarse sand for packing. If the basket is large compared with the size of the plant, additional chips are added so the ratio of moss to chips is roughly ½ by volume. Also, for species from calcareous regions, such as *Paphiopedilum stonei,* and *Paphiopedilum niveum*, a small amount of aragonite aquarium sand is added (for more calcium and pH balance). Almost all baskets have been seeded with various local live mosses. The additional aeration, alkaline amendments, and frequent flushing with slightly alkaline irrigation water maintain suitable pH levels in the root zone over multiple growing seasons. However, one needs to be judicious in the level of alkalinity maintained in the root zone, since the uptake of different forms of nitrogen (i.e., ammonium vs. nitrate) are dependent on the alkalinity concentration. Higher levels of alkalinity favor the uptake of ammonia relative to nitrate. Subsequently, the use of high nitrate fertilizers are preferred in low alkalinity ("pure water") growing conditions.

All organic potting substrates have varying degrees of cation exchange capability. However, CHC appears to have the greatest capacity, followed by fir bark, followed by moss. Provided that potassium is always presented at concentrations substantially lower than the divalent cations, and the potting mix is amended with some readily available form of calcium or dolomite, "souring" or "poisoning" of the organic component of potting mixes by potassium should be minimized, greatly extending the effective life of the potting mix. I would speculate that the dolomitic lime composting procedure used to process Orchiata Bark is a primary reason this potting material has demonstrated good success for many growers recently.

After roughly two years of working with this reduced potassium and high calcium and magnesium fertilizing regime I am pleased with the results. Leaves are larger, stiffer and shinier. *Erwinia*, mealybug and scale problems are greatly reduced. Plants that were in decline are rebounding. Seedlings are transitioning out of compots into individual pots without stalling and dying. Four of my plants even received AOS quality awards in the last year. I realize that two years is a small time frame with regards to orchid culture so time will tell if these short-term results are meaningful. In the meantime, I'll be assessing and tweaking. The Zotz 2004 data showed the influence of ants on the nutritional status of their tended plants. I only have a small number of ant-favored species in my collection (such as gongoras and coryanthes), so they may warrant closer attention and maybe some additional potassium during their fast growth periods. Watching, testing, trying new things — what a glorious hobby!

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[6–7] Four years ago this *Phalaenopsis pulcherima* 'Fuchsia Fantasy', AM/AOS, [6] was a stunted purple-leaved plant the author could not get to bloom. Increasing calcium and magnesium brought the plant back to green and flowering [7]. Reducing the potassium induced the best blooming and an 86-point Award of Merit.

[8] These *Paphiopedilum mastersianum* seedlings (that came out of flask in April 2010) are shown above in July 2012 after 1½ years of exposure to the low-potassium-high-calcium-and-magnesium strategy (July 2012). This species is considered a slow-growing and difficult one, but as of February 2013 (less than three years out of flask) no seedlings have been lost. The largest plant has a leafspan of 12-inches (30-cm) and is in bud. Also note the stiff shiny substance of the leaves.