The photos were over exposed from too much light. We could not seem to capture the beauty and true color of the flowers. One evening, we tried turning the flashes off and using flashlights as the source of light. It worked. I held the flashlights, strategically placed, on the open flowers while she shot the pictures. The end results were satisfying and captured the real colors of the flowers.

Vriesea gigantea flower. Photograph by Carol Wolfe

Late one night while making pictures, we saw an unusual small lizard about 7 inches long with light beige skin setting on the leaves. This was our first time to see this particular lizard on any of our plants. It sat contently while we made our nightly quota of photographs. Hopefully he did his share of pollinating the flowers after we left.

Vr. gigantea adapts well to central and south Florida gardens where the humidity is very high most of the time and the temperatures are usually warm to hot. However, under the canopy of a very large oak tree it has withstood winter temperatures as low as 20˚F many times and sustained below freezing temperatures for as long as 72 hours.

As you can see from the plant description, it isn't your typical window sill plant or even greenhouse plant. During blooming as the inflorescence became heavier and heavier, we had to add some ties to the oak tree to support it. Vriesea gigantea is a great foliage plant and with the inflorescence lasting several months, it is a very worthwhile plant to enhance your landscape.

We are now into August and the last flowers are opening, the spent blooms are drying up, but it has brought us many hours of enjoyment watching it grow, making our nightly vigils to see the flowers, and learning to photograph at midnight with flashlights in hand.

Sources and Strengths of Nitrogen in Tillandsia Propagation

Andrew Flower, BSI Editor

Introduction

At my nursery, Anwyl Bromeliads, we ran an observational trial to check the effects on epiphytically-grown tillandsia seedling growth rates of increasing nitrogen supply and also differing sources of nitrogen. We delivered nitrogen sourced from nitrate, ammonium and urea in three different combinations supplied in five different strengths between 2 and 4 millimols nitrogen per litre.

Figure 1. Group of tillandsia seedlings at the conclusion of the trial.

Plants need access to various elements in addition to their primary requirement for the energy in sunlight. In order to carry out the processes by which they manufacture energy-containing substances for future use by themselves (or their consumers). Carbon [C], hydrogen [H], and oxygen [O], are obtained from carbon dioxide [CO_2] or water [H_2O]. A number of other elements are needed to facilitate the various chemical reactions going on in plants, and these are obtained from mineral salts dissolved in water absorbed through the plant's roots or leaves. Of these nitrogen [N], is the element required in the largest amount, and it can be taken from three different sources in water: ammonium [NH_4], nitrate [NO_3] and urea [$CO(NH_2)_2$]. Ammonium and nitrate molecules are available in dissolved salts such as ammonium nitrate and calcium nitrate respectively. Urea is dissolved in water as an intact molecule that is rapidly decomposed by bacteria in soil, but taken up intact in solution by plants, such as tillandsia, that absorb water through their leaves.

We have these three different sources of nitrogen available for our cultivated plants. Why do we need to test which ones are the best? Commercial research over the years has shown that there are plusses and minusses to each of them.

Energy efficiency is important. Plants convert the energy in sunlight into short-term internally stored forms of energy to fuel the chemical reactions that are going on inside their cells, and in turn some of these reactions convert carbon, hydrogen and oxygen into longer-term forms of energy storage in the form of sugars and starches. So plants have to expend energy in the processes of manufacturing their food. It follows that the less energy needed to manufacture stored energy, the more effective the plant is. Nitrates and urea have to be converted into ammonium nitrogen by the plant before it can use the nitrogen, which apparently means that absorbing ammonium nitrate in the first instance will be more efficient.

Toxicity matters! High ammonium to nitrate-nitrogen ratios are toxic in most plants, and so we need to be cautious in the use of ammonium nitrate. Urea has had a lot of bad press. I asked a group of tillandsia growers at an Australian conference in 2006 how many of them would use urea on their tillandsias: no hands were raised. Leaf-burn is commonly attributed to urea, but this burning is actually caused by an impurity called "biuret" in the urea most commonly supplied for agricultural use. In our trials we used a detoxified product sold as "low biuret urea."

Side effects are a minefield. Nitrate nitrogen may increase the plant's uptake of calcium and boron, whilst ammonium nitrate reduces uptake of calcium and magnesium. Urea is thought to increase the penetration of other nutrients absorbed through the leaves, which could be very useful for tillandsia nutrition.

Materials and methods.

We started with single batches of tillandsia seedlings of five different species, and selected 25 plants of roughly the same size from each of them. One plant from each species was glued to a strip of plastic (figure 1) and these 25 strips were then dipped 95 times over the 120 days of the trial. A dipping consisted of submerging the batches for 5 seconds to approximate the amount of water being supplied by hand watering to the other occupants of the growing-on house they were living in. The dippings co-incided with the times we watered the normal stock of seedlings in the growing-on house, with the trial strips being left outside while the watering was in progress.

Each seedling was weighed individually at the start and finish of the trial, and then the 25 groups of 5 seedlings were sent to a commercial laboratory to be analysed for their mineral content. Due to the high cost of analysis, seedlings were analysed in their groups of 5, not individually.

All water used in the trials was demineralised by our reverse-osmosis system. Concentrated "stock" nutrient solutions were made up in groups of two 5 litre batches, labelled "A" and "B". This was necessary because the calcium nitrate has to be kept

in a different solution to the sulphates and phosphates to avoid having the calcium precipitate out. We then added 30 mls of each "A" and "B" stock solution to 3 litres of demineralised water to make the dipping solutions. Fresh dipping solutions were made up each month. The concentrated stock nutrient solutions were made up in three series:

"nitrate" with all solutions nitrate-nitrogen only (table 1);
"+NH_4" with increasing concentrations of ammonium-nitrogen in solutions 2-5 (table 2);
"+urea" with increasing concentrations of urea in solutions 2-5 (table 3).

Stock solutions were designed so that the composition of treatment solution 1 would be the same in each series, delivering 2 mmols of nitrogen and acting as a control. Treatment solutions 2 to 5 were designed so that they all received the same formula as solution 1, to which was added increasing amounts of nitrate-nitrogen in the nitrate series, increasing amounts of ammonium-nitrogen in the +NH_4 series and increasing amounts of urea in the +urea series. Thus the total amount of nitrogen delivered in each nutient series number was the same, only the nitrogen sources varied. Total nitrogen supply in the dipping solution for each series was 2, 2.5, 3, 3.5 and 4 mmols/litre in solutions 1 to 5.

The five species used were Tillandsia gardneri, T. ionantha, T. kautskyi, T. polystachia and T. stricta. They were selected because they were reasonably expendable insofar

Fertiliser	nitrate 1	nitrate 2	nitrate 3	nitrate 4	nitrate 5
A solution					
calcium nitrate, g	86.5	100.0	113.5	127.0	140.5
potassium nitrate, g	20.2	32.9	45.5	58.1	70.8
iron chelate, g	1.5	1.5	1.5	1.5	1.5
B solution					
mono-potassium phosphate	27.2	27.2	27.2	27.2	27.2
potasium sulphate, g	17.4	17.4	17.4	17.4	17.4
magnesium sulphate, g	49.3	49.3	49.3	49.3	49.3
60 g/l manganese chelate, ml	0.125	0.125	0.125	0.125	0.125
130 g/l zinc chelate, ml	0.0625	0.0625	0.0625	0.0625	0.0625
copper suphate, g	0.05	0.05	0.05	0.05	0.05
boric acid, g	0.75	0.75	0.75	0.75	0.75
sodium molybdate, g	0.05	0.05	0.05	0.05	0.05

Table 1. Nitrate series of stock solutions, delivering increasing concentrations of nitrate nitrogen.

Fertiliser	+ NH_4 1	+ NH_4 2	+ NH_4 3	+ NH_4 4	+ NH_4 5
A solution					
calcium nitrate, g	86.5	86.5	86.5	86.5	86.5
potassium nitrate, g	20.2	20.2	20.2	20.2	20.2
ammonium nitrate, g		10	20	30	40
iron chelate, g	1.5	1.5	1.5	1.5	1.5
B solution					
mono-potassium phosphate	27.2	27.2	27.2	27.2	27.2
potasium sulphate, g	17.4	17.4	17.4	17.4	17.4
magnesium sulphate, g	49.3	49.3	49.3	49.3	49.3
60 g/l manganese chelate, ml	0.125	0.125	0.125	0.125	0.125
130 g/l zinc chelate, ml	0.0625	0.0625	0.0625	0.0625	0.0625
copper suphate, g	0.05	0.05	0.05	0.05	0.05
boric acid, g	0.75	0.75	0.75	0.75	0.75
sodium molybdate, g	0.05	0.05	0.05	0.05	0.05

Table 2. Ammonium series of stock solutions; level 1 nitrate solution plus increasing concentrations of ammonium nitrogen.

Fertiliser	+ urea 1	+ urea 2	+ urea 3	+ urea 4	+ urea 5
A solution					
calcium nitrate, g	86.5	86.5	86.5	86.5	86.5
potassium nitrate, g	20.2	20.2	20.2	20.2	20.2
urea, g		7.6	15.2	22.8	30.4
iron chelate, g	1.5	1.5	1.5	1.5	1.5
B solution					
mono-potassium phosphate	27.2	27.2	27.2	27.2	27.2
potasium sulphate, g	17.4	17.4	17.4	17.4	17.4
magnesium sulphate, g	49.3	49.3	49.3	49.3	49.3
60 g/l manganese chelate, ml	0.125	0.125	0.125	0.125	0.125
130 g/l zinc chelate, ml	0.0625	0.0625	0.0625	0.0625	0.0625
copper suphate, g	0.05	0.05	0.05	0.05	0.05
boric acid, g	0.75	0.75	0.75	0.75	0.75
sodium molybdate, g	0.05	0.05	0.05	0.05	0.05

Table 3. Urea series of stock solutions; level 1 nitrate solution plus increasing concentrations of urea.

as we had a reasonable number of them, whilst trying to use a range of growth rates with T. kautskyi being one of the slowst we have grown, ionantha and gardneri among the fastest.

Results and discussion.

The trials were conducted over late spring and summer (southern hemisphere) and the 75 seedlings were weighed individually at the beginning and end of the trial. After photographing and weighing, the 15 sets of plants were dried and analysed.

	Nov 11, 2005	Mar 11, 2006	growth grams	growth %
nitrate				
soln. 1	3	5.6	2.6	86.66
soln. 2	3.4	7.5	4.1	120.58
soln. 3	4.3	9.1	4.8	111.63
soln. 4	3.7	8.9	5.2	140.54
soln. 5	2.9	6.6	3.7	127.59
+ NH_4				
soln. 1	4.0	8.5	4.5	112.50
soln. 2	3.2	7.4	4.2	131.25
soln. 3	2.5	6.6	4.1	160.78
soln. 4	3.2	6.9	3.7	115.62
soln. 5	3.1	6.6	3.5	113.00
+ urea				
soln. 1	3.9	7.3	3.4	87.18
soln. 2	3.4	7.5	4.1	120.59
soln. 3	3.35	7.5	4.15	123.89
soln. 4	3.2	7.2	4.0	125.00
soln. 5	3.5	8.1	4.6	131.40

Table 4. Combined weights, in grams, of five tillandsia species dipped in trial solutions

The goal of our trials is to optomise the growing of tillandsia species from seed, so this one was set up to mimic our actual production system. At any one time we have around 30,000 seedlings and the batches of any one population are mainly in the 30 to 50 range: very occasionally we raise 2-300 in a batch. Seeds are germinated on strips of mesh in an incubator, then moved to two growing-on houses where they are grown on hanging up on the meshes until they are large enough to be glued onto community sticks, then individual mounts. From germination until they leave the growing-on houses the seedlings are watered by hand using nutrients dissolved in demineralised water from the reverse osmosis plant. As mentioned before, the trial plants were dipped 95 times over 120 days, the same number of times the remaining plants in the growing-on houses were sprayed by hand using a single low throughput, fine SprayJet nozzle (young seedlings with a nozzle delivering 0.3 l/min., older seedlings with one delivering 1.9 l/min. This is enough to wet their leaves thoroughly). The growing-on house in which the

trial plants were hung was receiving carbon dioxide pumped in at night - the epiphytic tillandsias use a process called "CAM respiration" to take in carbon dioxide through their leaves at night to avoid doing it in the heat of the day when excessive loss of moisture cannot be quickly replaced because they have no ground-roots.

In reading the growth rate results, I find it is helpful to bear in mind the standard curve used to visualise the relationship between nutrient concentration and growth rate (Figure 2). At low nutrient levels growth will be retarded, and growth rates will increase as the supply of nutrient increases. At a certain nutrient level the growth rate will stabilise at the plant's maximum growth rate - this is shown in figure by the green column marked "adequate nutrition." But plants will not sustain their optimal growth rate if the nutrient concentration increases, and eventually a point will be reached when the nutrient becomes toxic and will kill the plant - this phase is shown by the red column. The optimal nutrient supply point is at the beginning of the green column in figure 2, just below 100 on the growth scale.

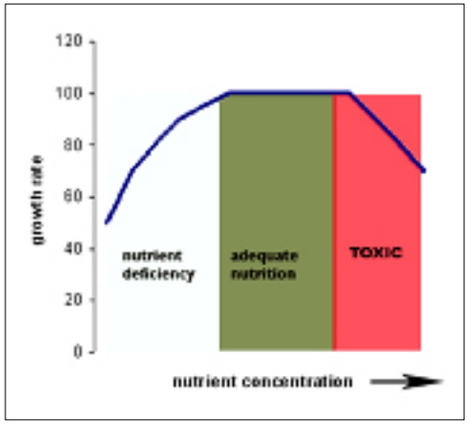

Figure 2. Relationship between plant growth and increasing nutrient levels.

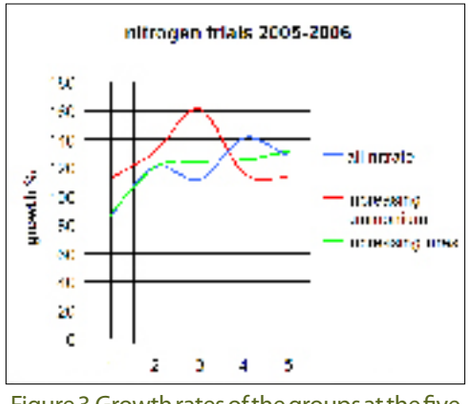

Figure 3. Growth rates of the groups at the five nutrient levels.

Trial plant growth during the trial is shown as percentages - a plant that doubled its weight in the trial period would show a 100% growth rate. My primary focus is on figure 3, the comparative growth rates between the full group of five plants in each sample. This is because we do not have the facility to tailor nutrient mixes to individual species, so must use the same nutrient mix and concentration for all seedlings across a wide range of species and from seed to flowering-size plant. Individual species growth is also shown in figures 4, 5 and 6.

Root development was quite strong in all samples, and a visual estimate showed the strongest development, by a small margin, was in the nitrate-only solution 1 series with 4 plants showing strong growth and 6 moderate growth (figure 7).

Figure 7. Strong root development on Tillandsia polystachia (top) and T. gardneri in nitrate-only solution 1.

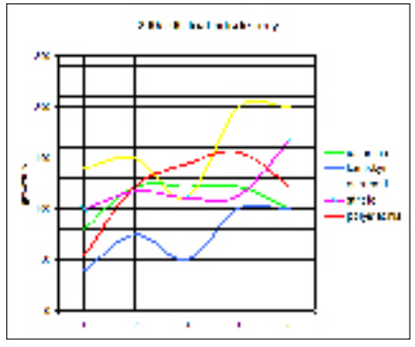

Figure 4. Growth rates of the individual species in the nitrate-only group.

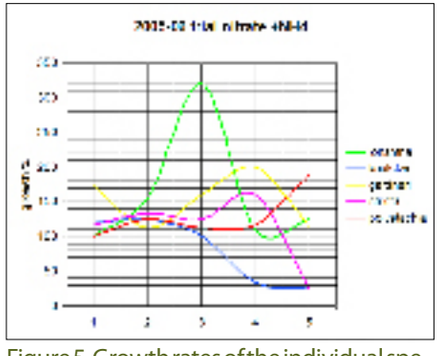

Figure 5. Growth rates of the individual species in the nitrate + ammonium group.

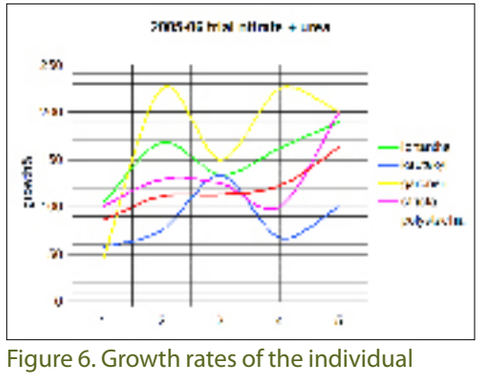

Figure 6. Growth rates of the individual species in the nitrate + urea group.

At the conclusion of the trial, the plants were packed up in their groups of five and sent off to Hill Laboratories in Hamilton to be dried and the ash analysed for mineral content. The analyses are shown in table 5, together with some comparative analyses under the heading "wild" at the bottom of the table. These are two samples of wild-grown Tillandsia circinnata reported in Benzing (1980, p. 61 & 63) and a benchmark list of the concentrations of mineral elements necessary for plant survival as formulated by Epstein (1972) and listed in Benzing (1980) and Taiz & Zeiger (1998).

Conclusions

These trials cannot be considered scientific: the samplings are way too small, and the experiments have not been duplicated. Our weighing and measuring equipment and their operation do not meet quality laboratory standards. But I do think this type of investigation beats the hell out of "shooting blind," and it has certainly helped us to bring the seedlings on much faster than we used to. The years taken to bring a tillandsia from seed to flowering-size are now half what they were ten years ago.

	nitrogen	phosphorus	potassium	sulphur	calcium	magnesium	sodium	iron	manganese	zinc	copper	boron
	N	P	K	S	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
nitrate	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
soln. 1	1	.26	1.5	.22	.68	.32	.10	277	64	100	25	26
soln. 2	1	.27	1.5	.21	.66	.29	.08	175	50	69	33	22
soln. 3	1	.25	1.6	.22	.62	.26	.09	163	47	61	24	24
soln. 4	1.1	.27	1.8	.28	.74	.24	.08	172	44	97	26	19
soln. 5	1.1	.25	1.8	.22	.71	.36	.07	158	45	73	21	23
+ NH_4 soln. 1	1	.29	1.4	.28	.6	.36	.07	136	45	73	17	19
soln. 2	1.1	.31	1.4	.28	.6	.36	.08	138	51	130	17	18
soln. 3	1.1	.28	1.2	.26	.6	.37	.06	139	47	100	19	20
soln. 4	1.4	.29	1.2	.30	.7	.35	.07	143	54	96	18	14
soln. 5	1.4	.27	1.1	.29	.55	.33	.08	154	50	91	21	19
+ urea soln. 1	0.9	.32	1.5	.25	.6	.38	.07	138	52	150	16	14
soln. 2	1.1	.29	1.4	.29	.6	.35	.07	130	49	90	13	15
soln. 3	1.2	.31	1.4	.30	.66	.39	.07	114	51	67	12	15
soln. 4	1.2	.29	1.3	.29	.62	.37	.06	137	54	83	12	16
soln. 5	1.3	.31	1.4	.27	.59	.36	.07	118	52	97	11	16
"wild" Benzing A	0.41	.10	0.49		.67	.25		153	27	38	9.2	16
Benzing B	0.46	.068	0.40		.68	.22		124	32.5	36.8	16.2	13.3
minimum	1.5	.20	1.0	.10	0.5	.20	.001	100	50	20	6	20

Table 5. Dry weight analysis of plant groups by dipping solution. Comparative analyses shown on bottom 3 rows are two samples of wild tillandsia (Benzing 1980) and the minimum level of nutrients said to be necessaery to sustain plant life (Epstein 1972)

Element		ppm
nitrogen	N	40
phosphorus	P	11
potassium	K	55
calcium	Ca	1.5
magnesium	Mg	9
sulphur	S	17
iron	Fe	0.35
+ trace elments		

Table 6. Theoretical delivery of major elements in our currrent nutrient solution.

This trial showed there is a slight improvement in growth rates at the lower nitrogen concentration (2.5 mmol/litre) if either urea or ammonium-N was added. But the ammonium nitrate addition showed a tendency to get toxic rather quickly from the 3.0 mmol N level onwards and I decided this is not an acceptable risk. I changed the nutrient formula for our nursery use over to the one used in the +urea series 2 trial.

I keep "bellweather" samples in our main growing-on houses to monitor growth by monthly weighing. Currently these are plastic strips with 12

plants of the same species glued on them. We changed to the new nutrient formula on June 14 2006, and in the 173 days between July 13, 2006 and January 2, 2007 the weight gain of each group of 12 plants was: Tillandsia butzii 37%, T. tenuifolia 40%, T. ionantha 35%. This period ran through late winter and a poor spring, reflected by the fact that seedlings were watered 91 times over 173 days whereas the nitrogen trial plants were dipped 95 times over 120 days. During this time we were not supplying extra carbon dioxide to the plants at night, as we were when the nirogen trials were being held.

Our seedlings are now being sprayed with the nitrate + urea series 2 stock solutions diluted at 2 litres of each "A" and "B" solution per 250 litres of demineralised water. At this rate the nitrogen delivery is a theoretical 2.8 mmols/litre. For the benefit of readers who think in terms of ppm, the delivery of mineral elements by this solution is shown in table 6. For those who always ask at conferences, the cF is around 4 - but bear in mind that urea does not ionize in water, so it has no effect on cF.

I acknowledge the assistance of our horticultural advisor, Dr. R.A.J. White.

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