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Potassium Nutrition Affects Leaf Growth, Anatomy, and Macroelements of *Guzmania*

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Additional index words. bromeliad, chlorophyll, mineral deficiency, water storage tissue

Abstract. ***Guzmania lingulata*** **(L.) Mez. 'Cherry' plants were grown in coconut husk chips. All plants were given 8 mM nitrogen (N), 2 mM phosphorus (P), 4 mM calcium (Ca), and 1 mM magnesium (Mg) at each irrigation with potassium (K) concentration at 0, 2, 4, or 6 mM. After 9 months, K concentration did not alter the number of new leaves, and shoot and root dry weights. Increasing K concentration did not affect the length but increased the width of the most recently fully expanded leaves (the sixth leaves). Plants under 0 K exhibited yellow spots and irregular chlorosis on old leaves being more severe at the middle of the blade and leaf tip. Numbers of leaves with yellow spots or chlorosis decreased with increasing K concentration. Chlorenchyma thickness was unaffected by K concentration, whereas water storage tissue and total leaf thickness increased with increasing K concentration. Leaf N concentration in the sixth or 10th leaf was unaffected by solution K concentration. However, plants at 0 mM K had higher N concentration in the 14th leaf than those in sixth and 10th leaves. Leaf P, Ca, and Mg concentrations decreased with increasing solution K concentration. K concentrations were higher in the sixth leaf than the 14th leaf in plants at 0, 2, or 4 mM K, whereas leaf K concentration was 15 g·kg^{-1} on dry weight basis in the sixth, 10th, or 14th leaves in plants treated with 6 mM K.**

Differential growth and quality responses to potassium (K) have been reported for foliage plants. Potassium deficiency is a widespread disorder on many palm species worldwide (Chase and Broschat, 1991). Under conditions of K deficiency, K from the oldest leaves is mobilized for use by the newly expanding leaves. Thus, removing potassium-deficient leaves accelerates rate of decline in *Phoenix robelenii* O'Brien (Broschat, 1994). The oldest leaves are more suitable for analyzing K status in coconut and Canary Island date palms (Broschat, 1997).

Although bromeliads have been widely used for indoor foliage plants or landscape decoration for decades, most research on K or other nutrient uptake in bromeliads has been done in their habitats (Benzing, 2000; Richardson et al., 2000). Published report on nutrient supply for production is presently limited. In one report, grade of *Aechmea fasciata* Baker was unaffected by increasing K from 50 to 150 mg/10-cm pot per month (Poole and Conover, 1976). The tropical foliage species *Aglaonema commutatum* Schott, however, did not respond to increased K from 80 to 320 mg/15-cm pot per month (Poole and Conover, 1977). *Spathiphyllum* 'Sensation' initially grew normally under K-deficient conditions with healthy appearance (Yeh et al., 2000).

Irregular yellowish areas on the old leaves have been observed on *Guzmania lingulata* (L.) Mez. 'Cherry'. These affected plants tend to produce incurved leaves after storage. Yellow spots on old leaves have been reported as symptoms of K deficiency for palms (Broschat, 1997), *Phalaenopsis* (Wang, 2007), and *Spathiphyllum* 'Sensation' (Yeh et al., 2000).

No controlled studies have been conducted to characterize the specific symptoms of *Guzmania* K deficiency and to quantify K requirements. The objective of this study was to determine the growth, leaf anatomy, and macronutrient concentrations of *Guzmania lingulata* 'Cherry' under various solution K concentrations.

Materials and Methods

Nonflowering plants of *Guzmania lingulata* 'Cherry' with 10 to 13 fully expanded leaves were planted in plastic containers containing 0.9 L of 1-cm diameter coconut husk chips commonly used for commercial production of bromeliad. The experiment was conducted from 30 May 2005 to 9 Mar. 2006 and all plants were grown in a 30% shaded greenhouse with an average noontime light intensity of 390 μmol·m^{-2}·s^{-1} and mean daily temperature of 25 °C. The uppermost leaf was marked for each plant for determining the number of new leaves to be produced. Nutrient solutions were made from K_2SO_4, $NaH_2PO_4{\cdot}2H_2O$, NH_4NO_3, $Ca(NO_3)_2{\cdot}4H_2O$, $MgSO_4{\cdot}7H_2O$, and $CaCl_2{\cdot}2H_2O$ to provide (in mM) 8 nitrogen (N), 2 phosphorus (P), 4 calcium (Ca), 1 magnesium (Mg), 2 sodium, and 2 chloride with K concentration at 0, 2, 4, or 6 mM. Plants were each fertigated weekly with 0.2 L of nutrition solution. Sulfate concentration increased from 0 to 3 mM as a necessary result of applying the K treatments. Tap water [electrical conductivity (EC) at 0.2 dS·m^{-1}] was used to prepare all solutions. The micronutrients of the tap water was (mg·L^{-1}) 0.017 iron and 0.016 zinc measured with an inductively couples argon plasma (ICP) emission spectrometer (Thermo Jarrell Ash Co., Boston, NY). At the end of experiment, the medium EC and pH were measured using pourthrough extracts (Wright, 1986). As K concentration increased from 0 to 6 mM, the medium EC ranged from 0.53 to 0.92 dS·m^{-1} as measured with a conductivity meter (SC-170; Suntex, Taipei, Taiwan), and pH increased from 5.7 to 6.0 as measured with a microcomputer pH meter (6171; Jenco Instruments, San Diego, CA).

At the end of the experiment, numbers of new leaves and leaves with yellow spots (≥1- to 2-mm diameter) or chlorosis were recorded in each treatment. The most recently fully developed leaf (leaf 6 from the apex) from all six plants in each treatment was sampled for measuring leaf length and width. Relative chlorophyll contents of the sixth and 15th leaves from all six plants in each treatment were measured in situ with a chlorophyll meter (SPAD-502; Minolta Camera Co., Tokyo). Three SPAD-502 readings were taken on the middle of the blade. Epidermis impressions were made on the fresh intact seventh leaves by applying a transparent glue, which covered ≈3 × 3 cm^2 of the abaxial surface. After drying (2 to 3 min), the imprints were removed from the leaf with a clear adhesive tape and mounted on a microscope slide. Stomatal frequency and percentage of opening stomata (numbers of opening stomata/total stomata number) were determined. Samples were taken from all plants, each with 10 replications per plant. The seventh 1eaf was cross-sectioned to measure leaf thickness. Shoots and roots were collected and oven-dried at 70 °C for 72 h to determine dry weights. Relative water content of the whole leaves was calculated as [(fresh weight – dry weight)/fresh weight] × 100%. Samples were taken from all treatments, each with six replications. Concentrations of N in leaves 6 (most recently expanded leaf), 10 (middle leaf), and 14 (old leaf) from all plants in each treatment were determined with the Kjeldahl procedure and that of P, K, Ca, and Mg were analyzed with an ICP emission spectrometer.

This experiment was arranged in a completely randomized design. Treatments were replicated six times with a single plant per replication. Linear and quadratic regression analyses were performed and presented using Sigma Plot 8.0 programming (SPSS, Chicago).

Results and Discussion

The number of new leaves and shoot and root dry weights were unaffected by K concentration in the nutrient solution (Table 1). Similarly, grade of *Aechmea fasciata* was

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unaffected by increasing K from 50 to 150 mg/10-cm pot per month (Poole and Conover, 1976). *Aglaonema commutatum* did not respond to increased K from 80 to 320 mg/15-cm pot per month (Poole and Conover, 1977).

Reducing solute K^+ provision may limit lateral cell expansion. The width of the most recently fully expanded leaves increased with increasing K concentration to 4 mM (Table 2). This is consistent with previous reports that K is known as the dominant osmoticum and contributes to cell enlargement and leaf expansion (Fricke et al., 1994; Fricke and Flowers, 1998; Shabala et al., 2000). Wang (2007) reported that *Phalaenopsis* produced wider leaves as K concentration in the nutrient solution increased.

The 0-K treatment reduced chlorophyll in the old leaves. Numbers of leaves with yellow spots and irregular chlorosis decreased with increasing K concentration (Table 2; Fig. 1). After treatments for 3 months, the old leaves on plants deficient of K began to exhibit yellow spots. Similar yellow spots as a result of K deficiency have been reported for palms (Chase and Broschat, 1991), *Phalaenopsis* (Wang, 2007) and *Spathiphyllum* 'Sensation' (Yeh et al., 2000). Symptoms of severe K deficiency were expressed as uneven chlorosis of old leaves being more severe at the middle of the blade and leaf tip.

Bromeliads have a unique water storage tissue to overcome drought stress. In *Tillandsia ionantha* Planch (Nowak and Martin, 1997), the cross-sectional area of the water storage tissue decreased rapidly and was completely exhausted after 50 d of drought treatment, whereas the cross-sectional area of the chlorenchyma declined by only 12%. Chlorenchyma thickness was unaffected by K concentration in *Guzmania*, whereas water storage tissue and total leaf thickness increased with increasing K concentration (Table 3; Fig. 2). Because *Guzmania* reduced leaf water storage tissue under K deficiency, the K-deficient leaves may be more susceptible to severe drought stress and become incurved.

Relative water content increased with increasing K concentration in *Guzmania* (Table 3), likely the result of increased water storage tissue. Stomatal frequency on the recently fully developed leaves was unaffected by K concentration, whereas the percentage of opening stomata decreased with increase in K concentration (Table 3). This is consistent with Arguero et al. (2006) who reported that K starvation increased g_S in olive trees, especially under water stress conditions. It is well documented that K serves a crucial function for cell osmoregulation, turgor maintenance, cell expansion, and stomatal function (Shabala, 2003).

Nitrogen concentrations in the 10th and 14th leaves were unaffected by solution K concentration (Fig. 3). The sixth leaves, however, had higher N concentration in plants under 0 K compared with those with 2 to 6 mM K. Increasing absorption of NH_4^+ can displace the role of K^+ in osmotic function (Xu et al., 2002), and that may explain why higher leaf N concentration in the K-deficient *Guzmania*.

Leaf P concentration also decreased with increasing solution K concentration (Fig. 3). Baghour et al. (2001) showed that increasing K fertilization resulted in reduced concentrations of inorganic, organic, and total P. Nitrogen and P are highly mobile, and thus N or P concentrations are lower in old leaves in N- or P-deficient plants (Mengel and Kirby, 1982). However, N and P concentrations are higher in the 14th leaf than the sixth leaf (Fig. 3), suggesting that *Guzmania* plants were not under N or P deficiency in the current experiment.

Leaf K concentration increased with increasing solution K concentration (Fig. 3). Except for the 6 mM K treatment, K concentrations were higher in the sixth leaf than the 10th or 14th leaves. New leaves in all *Guzmania* plants appeared healthy throughout this experiment. These clearly demonstrate that K is highly mobile in *Guzmania*. Similar to some palms (Broschat, 1997), the old leaves were a better indicator of *Guzmania* K status than the recently developed leaves. Because old leaves are a K reservoir, removal of K-deficient palm leaves can result in fewer symptom-free leaves and an accelerated decline from K deficiency (Broschat, 1994).

Table 2. Effects of potassium concentration on leaf length and width, SPAD-502 reading, and numbers of leaves with yellow spots and chlorosis of *Guzmania lingulata* Cherry.

Potassium concn. (mM)	Sixth leaf length (cm)	Sixth leaf width (cm)	SPAD-502 reading		Yellow spotted leaf no.	Chlorotic leaf no.
			Sixth leaf	15th leaf		
0	29.2	3.57	39.5	26.0	9.3	4.2
2	30.0	3.83	39.1	35.7	8.7	2.5
4	31.7	4.13	38.6	34.7	8.0	1.3
6	29.2	4.00	37.5	32.7	6.3	0.7
Significance	NS	L**Q**	NS	L**Q**	L**Q*	Q***

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively; L = linear; Q = quadratic.

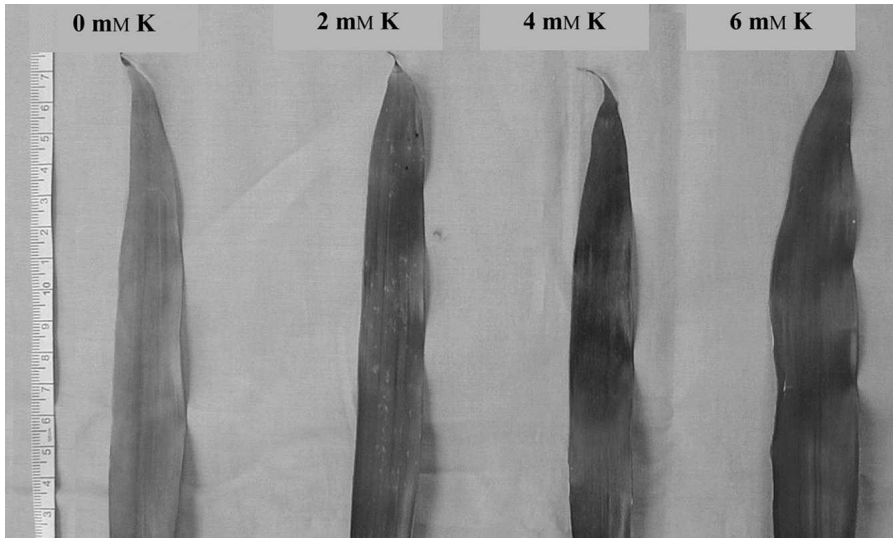

Fig. 1. Effect of potassium concentration on appearance of the 15th leaf of *Guzmania lingulata* 'Cherry'.

Table 1. Effects of potassium concentration on new leaf number and dry weights of *Guzmania lingulata* Cherry.

Potassium concn. (mM)	New leaf number	Shoot dry wt (g/plant)	Root dry wt (g/plant)
0	14.7	6.9	2.0
2	15.3	8.0	2.4
4	15.7	8.7	2.2
6	14.7	7.4	2.3
Significance	NS	NS	NS

NSNonsignificant.

Table 3. Effects of potassium concentration on leaf tissue thickness, stomatal frequency and percentage of opening stomata, and relative water content of *Guzmania lingulata* Cherry.

Potassium concn. (mM)	Thickness (0.01 mm)			Relative water content (%)	Stomata	
	Chlorenchyma	Water storage tissue	Total		No. per mm^2	Opening (%)
0	13.0	7.4	27.2	80.9	31.0	30.3
2	12.7	8.5	29.0	80.9	28.5	34.7
4	12.8	8.5	29.8	81.4	31.7	16.5
6	13.3	9.5	31.2	82.5	30.2	13.8
Significance	NS	L*Q*	L***Q***	L**Q**	NS	L*

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively; L = linear; Q = quadratic.

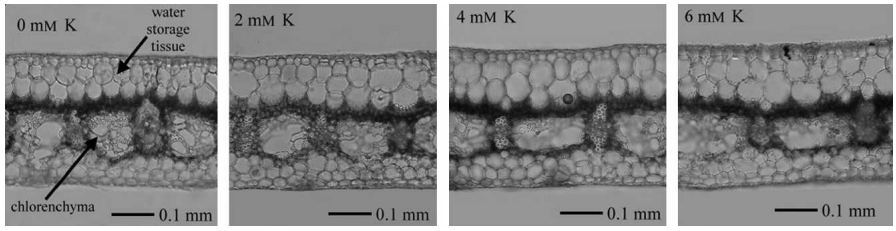

Fig. 2. Effect of potassium concentration on leaf anatomy of *Guzmania lingulata* 'Cherry'.

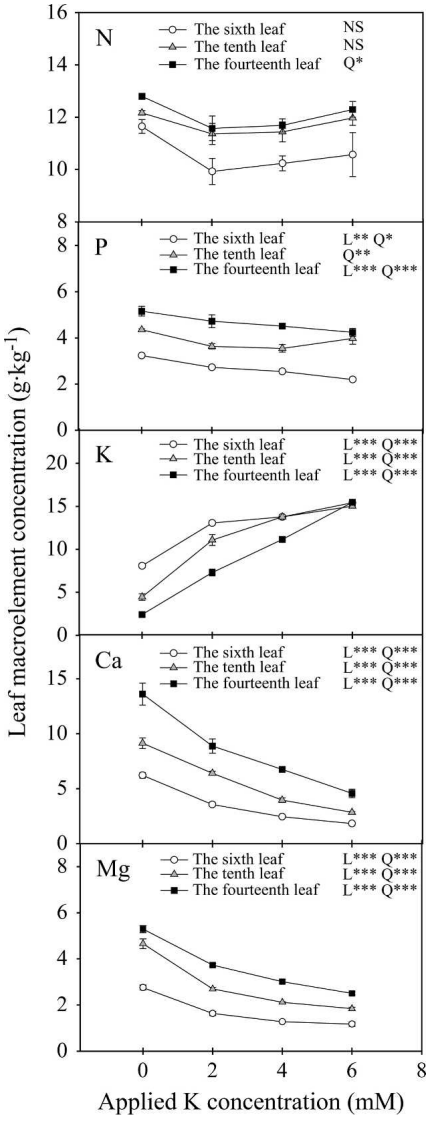

Fig. 3. Effects of potassium concentration and leaf position on leaf macroelement concentration of *Guzmania lingulata* 'Cherry'.

Our previous investigation on Guzmanias obtained from growers showed that leaf K concentration decreased gradually from leaf base (14.9 g·kg^{-1}), middle (11.0 g·kg^{-1}), to tip (7.9 g·kg^{-1}) in *Guzmania* 'Cherry', and that coincides with the K-deficiency symptoms expressed more on the tip and middle leaf portion. Similar to other monocots, a significant higher K^+ concentration was also measured at the growing leaf base than at the fully extended regions of corn (Mozafar, 1997), barley (Fricke and Flowers, 1998), and palm leaves (Broschat, 1997).

New leaf number and plant dry weights were not increasing at 6 mM K; however, numbers of leaves with yellow spots and irregular chlorosis decreased at 6 mM K (Tables 1 and 2). In the 6 mM K treatment, leaf K concentration was ≈15 g·kg^{-1} on a dry weight basis in all leaves sampled (Fig. 3). These suggest that applying 6 mM K may be just adequate for vegetative growth of *Guzmania*.

As solution K concentration increased, leaf Ca and Mg concentrations decreased (Fig. 3). The pattern of increasing K concentration resulting in decreased leaf Ca and Mg concentrations is well documented (Mengel and Kirby, 1982; Sabreen and Saiga, 2004). Ca is relatively immobile in plant tissues and Mg is probably immobile in some plant species (Fricke et al., 1995). Thus, the 14th leaves had higher Ca and Mg concentrations than the 10th or the most recently developed leaf (Fig. 3).

Conclusions

Plant dry weight of *Guzmania* was unaffected under K-deficient conditions. The 0 K-treated plants exhibited yellow spots and patches of chlorosis in old leaves that had 2 to 8 g·kg^{-1} K on a dry weight basis. Applying 6 mM K increased leaf width, thickness, and water content and reduced number of leaves with yellow spots or chlorosis. Recently developed leaves were appropriate for determining N, P, Ca, and Mg concentrations, but older leaves are more suitable for analyzing the K status in *Guzmania*. Leaves of healthy *Guzmania* plants may contain 15 g·kg^{-1} or higher K on a dry weight basis.

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Breeding and Micropropagation of *Aglaonema*

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Keywords: *Aglaonema*, flowering, chromosome, genetic relationship, micropropagation

Abstract

Breeding for *Aglaonema* (Araceae) cultivars with beautiful foliar variegation and color has long been the prevailing goal. The present works studied on regulation of flowering, chromosome number and genetic relationship to facilitate hybridization. Plants flower within 23 to 48 weeks, depending on the cultivar, following a single spray with 250 ppm gibberellic acid (GA_3). RAPD analysis on 61 accessions showed that *Aglaonema* genotypes are highly diverged and could be clustered into seven groups. Cultivars 'Curtisii' and 'Galaxy' are diploid (2n = 40), 'Pride of Sumatra' and 'Chalit's Fantasy' have 50 and 60 chromosomes, respectively. At least eight dominant alleles each with distinct pattern have been identified. Tissue culture is preferable for rapid multiplication of healthy plants. The inflorescence was an alternative source of explants to reduce endogenous microbial contamination, and the suggested cultural medium was half-strength MS basal medium with 5 to 10 µM Dicamba and 10 µM TDZ for direct shooting. After transferring to a shaded greenhouse, plants under 130 $\mu mol.m^{-2}.s^{-1}$ during ex vitro acclimatization had higher dry weight than those under 80 or 200 $\mu mol.m^{-2}.s^{-1}$.

INTRODUCTION

Aglaonema (Araceae) contains many cultivars that are important tropical foliage plants due to their tolerance of drought and low light and low relative humidity levels encountered under interior conditions (Chen et al., 2002). Breeding for cultivars with beautiful foliar variegation and color has long been the prevailing goal. Control of flowering by application of gibberellic acid sprays (Henny, 1983) and development of pollination techniques (Henny, 1988) led to the production of new cultivars. Knowledge of inheritance of foliar variegation (Henny, 1986) and genetic relationships of species and cultivars (Chen et al., 2004) make planning crosses easier. A part of this paper provides additional information on flowering time, inheritance of foliar variegation, and chromosome and genetic analysis of *Aglaonema* species and cultivars.

Commercial *Aglaonema* production almost exclusively starts from cuttings. Cutting propagation, however, may transmit pathogens from stock plants to cuttings. Tissue culture is preferable for rapid multiplication of healthy plants. Tissue culture has not been particularly successful with *Aglaonema* (Chen et al., 2003), largely due to endogenous microbial contamination. Reduced occurrence of contamination and browning in axillary bud explants excised from the stock plants of *Aglaonema* Schott 'White Tip' that had not been watered for 2 months (Chen and Yeh, 2007). However, drought stress might have detrimental effects on mother plants. The present works were to explore the possibility of using female flowers as explants for multiplication, to compare explants' growth using temporary immersion system (TIS) and semi-solid cultural system, and to determine the effects of photosynthetic photon flux (PPF) during ex vitro acclimatization on subsequent growth of micropropagated *A.* 'White Tip'.

REGULATION OF FLOWERING

To regulate flowering for pollination and hybridization, effects of temperature and/or GA_3 on flowering of Aglaonemas were studied under phytotron conditions. *A. commutatum* 'Emerald Beauty' increased flowering and number of inflorescences, after a single spray of 250 ppm GA_3 in late November under 30/25 and 25/20°C conditions for 7 weeks followed by transferring to 18-22°C greenhouse conditions (Table 1). None of the

plants without GA_3 treatment showed any sign of flowering when the experiment was terminated after 185 days. Similar flowering responses to temperature and GA_3 were observed in *Aglaonema commutatum* 'Pseudobracteatum', *Aglaonema* 'Silver Queen', and *A. commutatum* 'Elegans' (Chen and Yeh, 2003). These results are consistent with Henny (2000) showing that GA_3 treatment induces flowering of *Aglaonema* and many other ornamental aroids. Under a 60% shaded greenhouse at 18 to 32°C, *Aglaonema* species and cultivars flower within 23 to 48 weeks following a single spray with 250 ppm GA_3 (Table 2).

INHERITANCE OF FOLIAR VARIEGATION

The foliar variegation patterns were found to be governed by a single-locus, multiple-allelic system (Henny, 1986). Each distinct pattern is controlled by separate dominant alleles. These alleles are codominant, allowing for the expression of two variegation patterns in the same plants. At least eight dominant alleles each with distinct pattern have been identified (Chang, 2005; Henny, 1986).

CHROMOSOME NUMBER

The chromosome number varies from 2n = 42 to 60 or 120 (Nicolson, 1969) depending on species. Our investigation showed that cultivars 'Curtisii' and 'Galaxy' are diploid (2n = 40), while 'Pride of Sumatra' and 'Chalit's Fantasy' have 50 and 60 chromosomes, respectively (Fig. 1). *A. brevispathum* Jervis, *A. cochinchinense* Engl. and 'Silver Bay' also have 40 chromosomes. Our observation reveal that the species and cultivars, with 40 chromosomes as mentioned above, could produce pollens and set fruits, while cultivars 'Chalit's Fantasy' and 'Pride of Sumatra' failed to do so.

GENETIC RELATIONSHIP

The breeding of *Aglaonema* has been popular and caused the needs of genetic analysis. Due to highly interspecific hybridization, molecular characteristics are much more accessible than morphological investigation in studying genetic relationship. Chen et al. (2004) analyzed 54 *Aglaonema* species and cultivars by AFLP (amplification fragment length polymorphism) and showed that *A. commutatum*, *A. crispum* and *A. nitidum* derived cultivars clustered in the same group with similarity higher than 0.84. The revealed genetic relationship was in agreement with the *A. commutatum* was a species putatively derived from *A. nitidum*, *A. crispum*, *A. marantifolium* or *A. philippense* Engl., and *A. simplex* through introgressive hybridization (Jervis, 1980; Nicolson, 1969).

Chang (2005) analyzed the genetic relationship among the 61 *Aglaonema* accessions through RAPD (random amplified polymorphic DNA). The result indicated that *Aglaonema* genotypes are highly diverted and can be clustered into seven groups. The incongruity between group I or II and the last five groups (III, IV, V, VI, and VII) are very high. However, *A. brevispathum* (Engl.) Jervis f. *immaculatum* (III), *A. simplex* (V), and *A. rotundum*×*A. simplex* (V) were the exceptions which could be crossed to group I as pollen parent, and thus, conferred the incongruity between groups and severed as bridge cultivars. *A. pumilum* (IV), *rotundum* (V), and *pictum* (VI) are three species with less complicated genetic background and much distant from others. *A. costatum* N.E. Br. var. *costatum* f. *foxii* (Engl.) Jervis 'Foxii Grande' and *A. brevispathum* clustered to be group III. Group I could be divided into three subgroups, IA, IB, and IC, respectively. *A. rotundum*×*A. simplex* (V) was suggested as the paternal materials to transmit red pigment to other cultivars.

TEMPORARY IMMERSION SYSTEM (TIS) VS. SEMI-SOLID MEDIUM

Using TIS may increase the rate of multiplication, plant growth, and reduce cost of in vitro culture (Meira, 2000). The 0.5-cm node sections of 'White Tip', with 1-2 axillary buds for each section, were used as explants. More fresh weight and shoot number was measured in TIS than in semi-solid system (Table 3). More growth was measured in

explants with 1/2 MS macroelement strength for TIS, as compared with MS for semi-solid system (Chen, 2006).

INFLORESCENCES AS EXPLANTS FOR MICROPROPAGATION

Female flowers of 'White Tip' and 'Emerald Beauty' were sectioned, sterilized with NaOCl 0.5% or 1.0% for 5 to 15 minutes. Neither contamination nor browning occurred during in vitro culture period. Direct shooting was induced when cultured on1/2 MS basal medium with 5 to 10 μM Dicamba and 10 μM TDZ (Fig. 2). Using inflorescences as explants offers great promise since several *Aglaonema* plants could be propagated from a single inflorescence without significant damage to the mother plants.

EX VITRO ROOTING AND PPF DURING EX VITRO ACCLIMATIZATION

Indole-3-butytric acid (IBA) at 9.8 or 19.7 mM applied to the base of the microcuttings resulted in 100% ex vitro rooting and the longest roots (Chen and Yeh, 2007). Micropropagated plants were transplanted to a soilless mix and placed in a growth room at 25 ± 1°C under cool-white fluorescent light providing 16 h daily photosynthetic photon flux of 80, 130 or 200 $\mu mol.m^{-2}.s^{-1}$. After having been acclimatized for 70 days in the growth room, the plantlets were then transferred to a shaded greenhouse for 90 days and their growth was measured. Plantlets under 130 $\mu mol.m^{-2}.s^{-1}$ had subsequent greater growth (Table 4). Measurements of Fv/Fm value, photosynthetic rate indicated that plantlets under 200 $\mu mol.m^{-2}.s^{-1}$ exhibited photo-inhibition while photosynthetic rate under 80 $\mu mol.m^{-2}.s^{-1}$ was lower than 130 $\mu mol.m^{-2}.s^{-1}$ (Chu and Yeh, 2006).

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Tables

Table 1. Effects of temperature and 250 ppm GA_3 on flowering of *Aglaonema commutatum* 'Emerald Beauty'.

Treatment		Lowest flowering node	Mean no. inflorescences	Mean days to			
Day/night temp. (°C)	250 ppm GA_3			Visible spathe	Spathe unfolding	Female flowers discolored	Male flowers wilted
30/25	+	10.7a[z]	2.5a	156.2c	158.4c	162.7c	167.5c
	-	---[y]	---	---	---	---	---
25/20	+	11.0a	2.0b	160.0b	164.6b	169.0b	171.8b
	-	---	---	---	---	---	---
20/15	+	9.4b	1.0c	180.6a	185.1a	189.2a	194.9a
	-	---	---	---	---	---	---

[z]Mean separation within columns by LSD at $P \leq 0.05$.
[y]Still not flowered at the end of experiment

Table 2. Effects of 250 ppm GA_3 treatment on flowering of *Aglaonema* species or cultivars.

Species or cultivar	Days to flowering (weeks)		Flowering (month)	
	Year 2002	Year 2003	Year 2003	Year 2004
A. simplex	29-30	28-29	6	5-6
A. 'Angel Delight'	45-46	27-28	5-6, 9-10	5-6
A. 'Goden Bay'	24-25	28-29	8, 11-12	6
A. cohinchinenes	42-43	25-26	9	5-6
A. pictum 'Tricolor'	33-34	23-24	7	4-5, 7-10
A. 'Rembrandt'	29-30	28-29	5-6, 11	5-7
A. 'White Tip'	32-33	31-32	4-12	4-6, 8-9
A. crispum 'Fantasy'	34-35	28-29	4, 6-12	5-8
A. 'Silver Bay'	46-47	28-29	4-12	4-7, 9-11
A. 'King of Siam'	32-33	30-31	4-7, 10	4, 6
A. 'Emerald Beauty'	32-33	28-29	4-10, 12	5-7
A. 'Galaxy'	46-47	30-31	4, 6-12	6, 9-10
A. nitidum 'Curtisii'	32-33	31-32	4-12	4-12
A. pictum 'Bicolor'	34-35	33-34	7-8	7, 9
A. commutatum 'Pseudobracteatum'	32-33	32	5-8	7
A. commutatum 'Elegans'	33-34	28-29	5-8	5-7
A. 'Chalit's Fantasy'	26-27	28-29	4-6, 9-10	5-6
A. 'Sithiporn Green'	23-24	26-27	4, 7, 10	5, 8-9
A. 'Marry Ann'	46-47	28-29	5, 9-12	5-6, 9
A. 'Manila Whirl'	32-33	30-31	6-7, 10	5-6

Table 3. Effect of strength of MS macroelements on growth of micropropagated *Aglaonema* 'White Tip' in temporary immersion system (TIS) and semi-solid culture.

Strength of MS macroelements	Plant height (cm)	Fresh weight (g)	Shoot number	Root number
		TIS		
1/2	2.2±0.7 a[z]	0.7±0.2 a	5.1±1.3 a	0.9±0.3 a
1	1.7±0.5 b	0.6±0.2 ab	4.3±0.9 ab	0.8±0.4 a
2	0.9±0.3 cd	0.5±0.1 bc	4.0±0.7 b	1.1±0.3 a
		Semi-solid medium		
1/2	0.9±0.2 d	0.4±0.1 c	3.6±0.5 b	0.8±0.4 a
1	1.0±0.4 cd	0.4±0.1 c	4.3±0.8 ab	0.8±0.4 a
2	1.4±0.5 bc	0.4±0.1 c	3.5±0.5 b	1.1±0.5 a
Significance				
MS strength (M)	***	**	***	NS
System (S)	***	***	*	NS
M × S	***	NS	NS	NS

[z]Means separation within columns by LSD test at $P \leq 0.05$.
[NS, *, **, ***] Non-significant, or significant of at $P \leq 0.05$, 0.01 and 0.001, respectively.

Table 4. Effects of photosynthetic photon flux (PPF) during ex vitro acclimatization on subsequent growth of micropropagated *Aglaonema* 'White Tip'.

PPF ($\mu mol/m^2/s$)	No. of leaves	No. of roots	No. of shoots	Leaf area (cm^2)	Dry wt. (mg/plant)	
					Shoot	Root
80	7.8 a[z]	18.0 ab	3.2 b	43.7 ab	330.6 ab	113.0 b
130	7.6 a	23.6 a	5.4 a	67.1 a	605.5 a	182.2 a
200	6.8 a	12.6 b	3.8 b	36.7 b	297.7 b	50.3 b

[z]Mean separation within columns by LSD at $P \leq 0.05$.

Figures

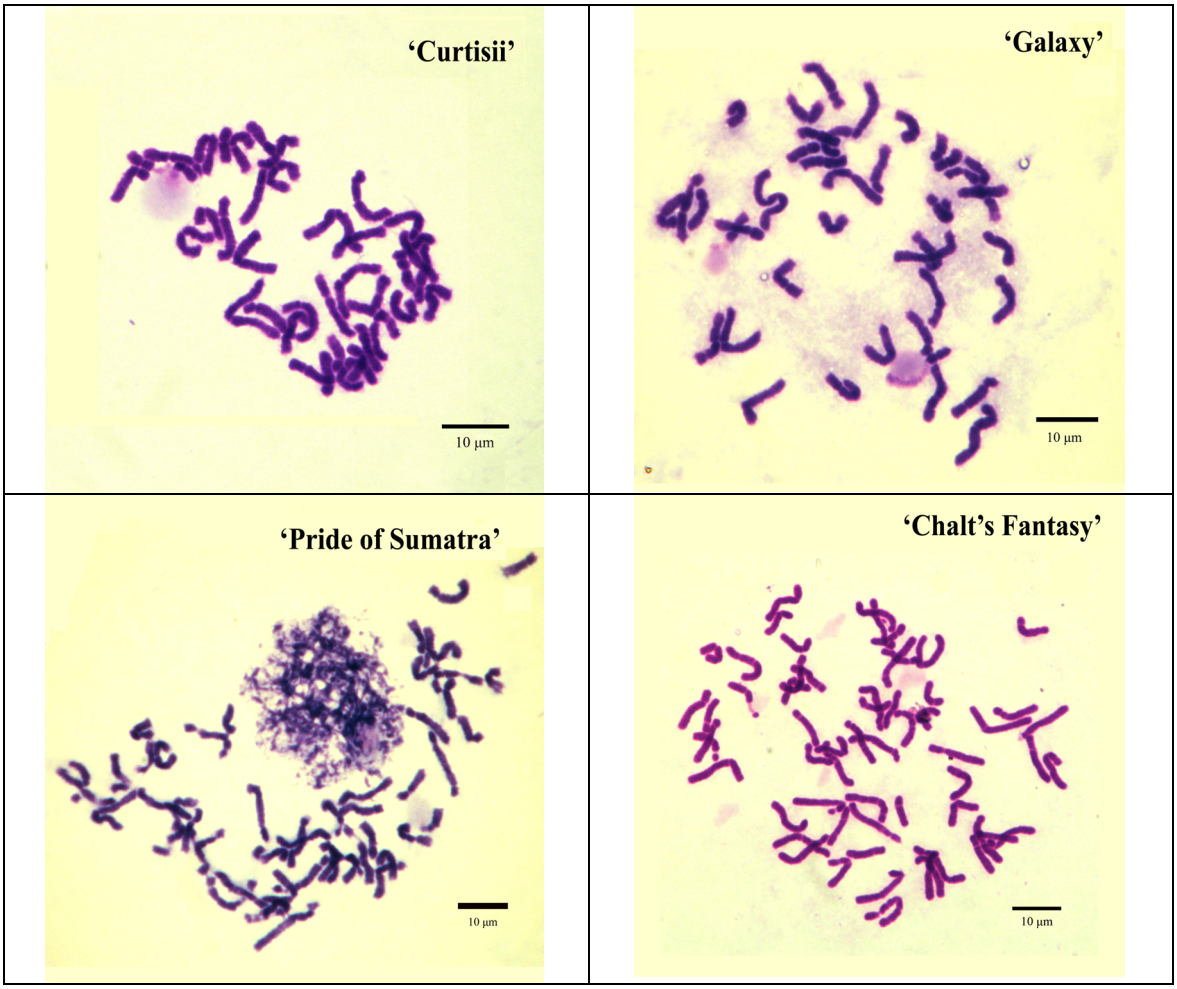

Fig. 1. Chromosomes of *Aglaonema* cultivars 'Curtisii', 'Galaxy', 'Pride of Sumatra', and 'Chalit's Fantasy'.

Fig. 2. Shoot multiplication from female flowers of *Aglaonema* 'White Tip' cultured in 1/2 MS basal medium with 10 µM Dicamba and 10 µM TDZ.