

**ALTERAÇÕES BIOQUÍMICAS E VISUAIS NA VIDA
PÓS-COLHEITA DE ANTÚRIO (*Anthurium
andraeanum* Linden ex Andre) EM RESPOSTA
A APLICAÇÃO DE CITOCININA**

BRUNO TREVENZOLI FAVERO

Tese apresentada ao Instituto de Biociências,
Câmpus de Botucatu, UNESP, para obtenção
do título de Doutor em Ciências Biológicas
(Botânica), AC: Fisiologia e Bioquímica
Vegetal

**BOTUCATU - SP
2014**

UNESP - UNIVERSIDADE ESTADUAL PAULISTA
INSTITUTO DE BIOCIÊNCIAS DE BOTUCATU

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“Success is not final, failure is not fatal: it is the courage to continue that counts.”

Winston Churchill

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RESUMO – O manejo pós-colheita adequado é fundamental para a manutenção da durabilidade de flores de corte e o uso dos tratamentos contendo reguladores vegetais tem se mostrado positivo para este propósito. Os objetivos deste trabalho foram: testar o efeito da 6-benzilaminopurina na solução de condicionamento e por aspersão na pós-colheita de antúrios (*Anthurium andraeanum*) cv. Apalai (IAC NK 130), avaliando a durabilidade, a variação do peso fresco, o teor de carboidratos solúveis, o teor de compostos fenólicos totais e a atividade da enzima polifenol oxidase; e avaliar o efeito das soluções de hidratação e condicionamento, do uso de espuma floral, da aplicação de tiosulfato de prata seguida da aplicação de etileno e do produto comercial Fresco[®] na vida de vaso de quatro variedades de *Curcuma alismatifolia*. O uso de 6-benzilaminopurina (BAP) na pós-colheita de antúrios foi benéfico quando aplicado por meio de aspersão, quando este regulador de crescimento foi adicionado à solução de condicionamento houve redução da vida de vaso de 17,9 para 13,8 dias, respectivamente; e também proporcionou melhor manutenção do peso fresco inicial, 93 % e 76 % respectivamente. Observou-se maior concentração de carboidratos solúveis na espata de hastes tratadas com menos de 150 mg L⁻¹ de BAP. O teor de compostos fenólicos totais foi maior nas hastes submetidas a solução de condicionamento do que as que receberam BAP por meio de aspersão. Portanto, recomenda-se o uso de BAP por aspersão para aumentar a durabilidade de antúrios cv. Apalai. O experimento com as hastes de cúrcuma mostrou que esta espécie não responde positivamente aos tratamentos pós-colheita mais comuns e assim recomenda-se manter as flores em água deionizada. O uso de espuma floral tem efeito negativo na vida de vaso de hastes de cúrcuma.

Palavras-chave: 6-benzilaminopurina, BAP, fenóis totais, carboidratos, polifenoloxidase, cúrcuma, siam tulip, durabilidade, espuma floral

INTRODUÇÃO

A floricultura brasileira em expansão mostra uma grande variedade de espécies produzidas e disponíveis para os mercados interno e externo. Dentre as práticas de manejo, os produtores de flores tem grande especialização devido a necessidade de fornecer produtos com alta qualidade.

A manutenção da qualidade das flores será máxima com uso adequado das técnicas de conservação pós-colheita, mantendo assim a aparência de recém-colhida. O manejo pós-colheita pode incluir o uso de soluções contendo bactericidas, agentes acidificantes, açúcares, reguladores vegetais e substâncias anti-etileno.

Cada espécie pode responder de forma diferente aos tratamentos citados e portanto é importante que sejam realizados experimentos para entender estas diferenças, provendo informações seguras para que os produtores e varejistas abasteçam o mercado com flores de qualidade.

Os objetivos deste trabalho foram: testar o efeito da 6-benzilaminopurina na solução de condicionamento e por aspersão na pós-colheita de antúrios (*Anthurium andraeanum*) cv. Apalai (IAC NK 130), avaliando a durabilidade, a variação do peso fresco, o teor de carboidratos solúveis, o teor de compostos fenólicos totais e a atividade da enzima polifenol oxidase; e avaliar o efeito das soluções de hidratação e condicionamento, do uso de espuma floral, da aplicação de tiosulfato de prata seguida da aplicação de etileno e do produto comercial Fresco[®] na vida de vaso de quatro variedades de *Curcuma alismatifolia*.

REVISÃO DE LITERATURA

1. Antúrio

O antúrio (*Anthurium andraeanum* Linden ex Andre) pertence ao Filo Magnoliophyta, à Classe Liliopsida, à Ordem Alismatales e à Família Araceae, que compreende aproximadamente 108 gêneros e 3.750 espécies, das quais a maioria (2/3) são nativas dos trópicos (Croat, 1998; Viegas et al., 2007).

O gênero *Anthurium* compreende mais de 600 espécies (Souza, 1958) e dentre as espécies conhecidas, o *A. andraeanum* Linden ex Andre (Linden & Andre, 1877; Bisby et al., 2010) é o mais popular de todo o gênero, destacando-se dos demais devido ao tamanho, a coloração e a longevidade de suas flores (Matthes & Castro, 1989). O antúrio é uma planta semi-herbácea, ereta, perene, originária da Colômbia, com 0,3-1,0 m de altura, de folhagem ornamental; as flores são brancas, cremes ou esverdeadas, formadas na primavera e verão e ornadas por espatas sulcadas, em diversas cores de acordo com a variedade hortícola (vermelha, branca, verde, marrom) (Lorenzi & Souza, 2008).

A floricultura brasileira tem como principais características ser praticada em pequenas áreas e com marcante fisionomia de agricultura familiar (Castro, 1998). Apresentando grande importância econômica para o país, essa atividade movimenta uma grande parcela da economia de vários Estados brasileiros, como Alagoas, Amazonas, Bahia, Ceará, Goiás, Minas Gerais, Santa Catarina, São Paulo, Rio de Janeiro, Rio Grande do Sul e Pernambuco, sendo São Paulo o principal Estado produtor de flores e plantas ornamentais, que representa, de acordo com Matsunaga (1997), 70 % da produção nacional.

O antúrio se destaca entre as outras espécies ornamentais tropicais cultivadas devido a sua beleza, durabilidade e longevidade pós-colheita (Gantait & Mandal, 2010) e a expansão mundial da cultura do antúrio é decorrente do desenvolvimento e lançamento de novas variedades entre os anos de 1998 e 2002, pelo Instituto Agrônomo de Campinas, e em 2003, pela empresa holandesa Anthura (Leme, 2004).

A qualidade pós-colheita das flores e plantas ornamentais está diretamente ligada às condições ambientais e manejo a que são expostos os produtos no campo, durante seu desenvolvimento, até o ponto ideal de colheita. É sabido que o tratamento pós-colheita não melhora a qualidade original do produto, mas apenas a mantém e dependendo de sua eficácia pode prolongar sua vida útil (Pinto, 1997).

As hastes de antúrio devem ser colhidas com o pedúnculo floral firme e três quartos da espádice madura, observados a partir da alteração da coloração, recomenda-se apenas a limpeza da espata com água quando necessário. A classificação é feita por tamanho das hastes em pequeno (menor que 30 cm), médio (entre 30 e 45 cm) ou grande (maior que 45 cm). As hastes que apresentam deformidades, manchas ou perfurações nas espatas devem ser descartadas (Loges et al., 2005). Os motivos mais comuns de rejeição de hastes de antúrio são as doenças e as injúrias causadas por insetos, estresses ambientais ou por danos mecânicos oriundos da colheita, manuseio e transporte (Bushe et al., 2004).

A qualidade de antúrios traduz-se como a longevidade pós-colheita, destacando-se os atributos cor e diâmetro da espata e comprimento da haste. Estas características podem ser influenciadas pela variedade, pelo manejo pré-colheita, bem como pelo uso de técnicas de conservação pós-colheita (Aki, 2008; Viradia & Singh, 2004). Em uma pesquisa de mercado realizada no Havaí com 73 floristas do varejo mostrou que a longevidade pós-colheita e a cor são os fatores decisivos para a compra de antúrios e que são esperados entre 10 e 15 dias de mínima durabilidade pós-colheita para 44 % e 44 % dos entrevistados, respectivamente (Halloran & Kuehnle, 1998).

Entre os principais problemas que a floricultura brasileira tem que superar está o manejo pós-colheita inadequado. Ainda faltam conhecimentos e tecnologias de colheita e pós-colheita que visem à redução de perdas, que no Brasil chega a atingir 40 % da produção, e o atraso da senescência (Dias-Tagliacozzo & Castro, 2002).

A senescência das flores de antúrio é acompanhada de mudanças visíveis que incluem perda do brilho da espata, necrose da espádice, azulamento da espata, colapso da haste, e abscisão da espata e da espádice da haste (Paull, 1982). Para assegurar a manutenção da qualidade das flores de antúrio é necessária a utilização de tratamentos pós-colheita visando à extensão da vida de vaso e ao atraso da senescência (Thawiang et al. 2007).

As citocininas são uma classe de hormônios vegetais as quais produzem diversos efeitos ao longo do desenvolvimento das plantas, incluindo a dominância apical, a formação e ativação de meristemas, senescência foliar, mobilização de nutrientes, crescimento da raiz na germinação de sementes e respostas ao estresse (Barciszewski et al. 2007).

A senescência é fortemente modulada por hormônios vegetais, como qualquer outro estágio de desenvolvimento das plantas (Skutnik et al., 2001) e o uso de reguladores vegetais

para prolongar o período de armazenamento pós-colheita de espécies vegetais é uma opção viável e interessante. Já foi constatado que a aplicação exógena de reguladores vegetais, como giberelinas ou citocininas, interfere na senescência de folhas. Isso foi claramente observado em *Matthiola incana* L., quando a aplicação de 5 ou 10 μM de thidiazuron (TDZ), um composto contendo fenil-uréia com atividade similar às das citocininas, através de solução de condicionamento por 24h resultou em atraso do amarelecimento foliar em 30 dias, para ambas concentrações (controle: 7 dias) e da murcha das pétalas em 10 e 11 dias, respectivamente (controle: 8 dias) resultando em 10 e 11 dias de vida de vaso (controle: 7 dias) (Ferrante et al. 2009).

Muitos efeitos são atribuídos às citocininas no prolongamento da longevidade das flores colhidas. MacLean e Dedolph (1962) sugerem que a citocinina retarda a senescência de flores, em função da redução da taxa respiratória. Estudos com plantas tropicais mostraram que a resposta à citocinina varia muito em folhagem e que esta variação de resposta na longevidade das hastes florais depende da espécie, da época do ano em que ocorre a colheita e da cultivar (Paull & Chantrachit, 2001).

Soluções à base de citocinina têm sido aspergidas diretamente sob a parte aérea, para estender a vida de prateleira de plantas envasadas, pois este regulador promove a maturação de cloroplastos e retarda a senescência de folhas destacadas (George, 1993), sendo usada na conservação pós-colheita de flores e plantas envasadas, preservando-se assim, a qualidade e vigor foliar. Paull e Chantrachit (2001) ao aplicarem por aspersão ou imersão das hastes em solução contendo 100 mg L⁻¹ de 6-benziladenina, estenderam a vida de vaso de antúrio (*Anthurium andraeanum*), helicônias (*Heliconia psittacorum* cv. Andromeda, *H. chartacea* cv. Sexy Pink) e de inflorescências rosa e vermelha de *Alpinia purpurata*. BA e metanol aumentaram a vida pós-colheita de flores de crisântemo, mantendo a coloração das folhas e flores e retardando a senescência (Petridou et al., 2001).

Visando manter a qualidade pós-colheita de *Anemone coronaria*, *Bougainvillea glabra*, *Eustoma grandiflorum*, *Grevillea* e *Phlox paniculata* foram aplicados diversos tratamentos pós-colheita a base de citocininas e auxinas e devido às limitações do uso de reguladores em virtude da ineficiência de translocação da solução de condicionamento para o tecido alvo foi incluído o tratamento de imersão, para flores cortadas, e aspersão, para flores em vaso (Meir et al. 2007).

A vida de vaso e de prateleira de minicrisântemos da variedade Rage foram prolongadas com a aplicação de 0,5 mM de 6-benzilaminopurina, atrasando o descarte em 11 dias, o que correspondeu a um aumento em mais de 50 % na vida de vaso, igualando-a as variedades Summer Time e Davis (Barbosa, 2006). Esses resultados suportam o trabalho realizado por Musgrave (1994), o qual sugere que as citocininas funcionam como captadoras de radicais livres e mantém esta atividade em alta, o que resulta na inibição da senescência. Chaitanya e Naithani (1998) argumentam que a citocinina inibe e/ou reduz danos à membrana por suprimir o estresse oxidativo via aumento da atividade da enzima superóxido dismutase, a qual poderia reduzir a peroxidação dos lipídios.

A aspersão de 200 mg L⁻¹ de 6-benzilaminopurina às hastes de alpínia associado à solução de 1 % de sacarose e ácido cítrico, aumentou a longevidade comercial e total em aproximadamente 10 dias. Em hastes que receberam somente aspersão de 6-benzilaminopurina, o aumento da longevidade comercial foi de aproximadamente 8 dias e a total de 6 dias em relação à testemunha (Dias-Tagliacozzo, 2003). Em hastes de sorvetão (*Zinziber spectabile* Griff.), o tratamento com solução contendo 6-benzilaminopurina (BAP) 10 mg L⁻¹ não resultou em aumento na vida pós-colheita (Santos et al., 2008).

No passado, os antúrios eram tratados com soluções contendo nitrato de prata (Castro, 1998), apesar de ainda existirem trabalhos que recomendam o uso dessas substâncias, nos últimos anos, a tendência mundial vem sendo usar soluções atóxicas.

Dias-Tagliacozzo e Castro (2001) verificaram que se logo após a colheita de hastes de antúrio comercial forem mantidas por 24 horas em solução de condicionamento a longevidade de variedades importadas cultivadas e comercializadas no Brasil pode ser prolongada em relação às mantidas somente em água. Isso se justifica pelo fato do antúrio ser pouco sensível ao etileno e, portanto, não existe necessidade de se usar nitrato de prata ou outras substâncias utilizadas para prevenir o efeito do etileno.

Santos e colaboradores (2008) observaram que a solução contendo 75 mg L⁻¹ de nitrato de prata apresentou a melhor conservação pós-colheita, segundo escala de notas, de hastes de sorvetão (*Zinziber spectabile* Griff.), seguida da solução contendo 5 mg L⁻¹ de ácido giberélico (GA₃) e a maior perda de massa fresca em relação ao tratamento controle foi observada nas hastes tratadas com solução contendo 6-benzilaminopurina (BAP).

Para avaliar a vida pós-colheita de flores e inflorescências, em geral se utiliza análises visuais, físicas e bioquímicas. As análises visuais em geral são baseadas numa escala de notas, onde se estabelecem critérios que são observados ao longo do experimento. As análises físicas da conservação de hastes florais consistem da pesagem da massa de matéria fresca diariamente ou em dias alternados, quando o armazenamento é úmido é possível quantificar o volume de solução absorvido pelas hastes ao longo dos dias, aferição de pH de solução conservante, entre outros. As análises bioquímicas buscam estudar marcadores bioquímicos de senescência, dentre esses, podemos destacar os carboidratos, os compostos fenólicos, atividade de enzimas oxidativas.

As flores, normalmente funcionam nas plantas como drenos, onde há maior necessidade de açúcares para a manutenção do metabolismo. Durante a pós-colheita essa necessidade tende a aumentar, já que ocorre a manutenção das folhas e essas funcionam como fonte, ou seja, transformam principalmente o amido em moléculas menores, açúcares solúveis, que são translocados para as flores e, provavelmente, como observado por Laschi (2000), para a região do pescoço (drenos).

O acúmulo de glicose deve-se ao fato de, ao ser retirada da planta, a flor comporta-se como um dreno, ocorrendo translocação das folhas para os tecidos das pétalas. Esse transporte ocorre em forma de sacarose (açúcar de transporte) para, ao atingir as flores, formar glicose (Taiz & Zeiger, 2013). As folhas funcionam como fonte, onde o carboidrato de reserva (principalmente amido) se transforma em açúcar solúvel, principalmente sacarose e é transportado desta forma para o caule. A sacarose é reduzido por hidrólise pela ação de invertases, liberando açúcares solúveis (glicose e frutose) e assim aumentando sua concentração (Laraa et al., 2004).

Eason e colaboradores (1997) observaram que os níveis de carboidratos, proteínas solúveis, carotenoides e clorofilas a e b diminuíram durante a senescência de flores de *Sandersonia aurantiaca*. As variações nos níveis de carboidratos em flores têm sido relacionadas com a extensão da vida de vaso de flores e segundo Ichimura e colaboradores (1999) houve alta correlação ($r=0,892$ $p<0,01$) entre a vida de vaso e o teor de carboidratos solúveis em pétalas de rosa.

A oxidação enzimática de compostos fenólicos pela peroxidase (POD) e polifenoloxidase (PPO) resulta, reconhecidamente, no escurecimento de tecidos vegetais. Há

uma classe de enzimas que catalisam a oxidação de mono e difenóis para quinonas, conhecidas como polifenoloxidasas, fenolases, tirosinases, catecolases e cresolases. Essas enzimas estão envolvidas na formação de materiais poliméricos coloridos, que provocam reações que podem ser chamadas de “escurecimento enzimático” ou “melanização” (Yoruk & Marshall, 2003; Mayer, 2006).

As PPO podem estar localizadas no cloroplasto, onde estão associadas com a membrana interna do tilacoide. Podem também ser encontradas no citosol e em vesículas entre o plasmalema e a parede celular (Obukowicz & Kennedy, 1981). Muitos fenólicos estão presentes principalmente nos vacúolos, mas são sintetizados no citosol (Vamos-Viagyázó, 1981) e podem às vezes, serem depositados na parede celular.

Danos nas membranas de organelas tais como vacúolos, fazem com que os fenóis entrem em contato com as polifenoloxidasas (Leja et al., 2003) promovendo sua atividade. Muitas células podem reagir aos danos celulares e depositar compostos fenólicos na parede celular, os quais poderiam então reagir com as polifenoloxidasas presentes no apoplasto.

A participação das PPO foi evidenciada na murcha de crisântemo (*Dendrathera grandiflora*), de Bouvardia, de *Acacia holosericea*, e de ave do paraíso (*Strelitzia reginae*). A injúria provocada corte das hastes promove o rompimento celular e o contato entre enzima e substratos, fenóis e oxigênio, e pode ser observado após alguns dias o aumento na atividade das enzimas catecol oxidase e também peroxidase, mostrando também o envolvimento de espécies reativas de oxigênio (Ratnayake et al., 2011; Guimarães et al., 2010; van Doorn & Vaslier, 2002; Vaslier & van Doorn, 2003).

2. Cúrcuma

A cúrcuma (*Curcuma alismatifolia* Gagnep.) pertence à família Zingiberaceae que esta sob a ordem Zingiberales das monocotiledôneas e é um gênero importante dentro desta família. A família Zingiberaceae é composta por 47 gêneros e 1400 espécies de herbáceas perenes tropicais (Nair, 2013). A origem exata da cúrcuma é desconhecida, entretanto é seguro afirmar que tem origem no sudoeste asiático (Velayudhan et al., 1999).

O gênero *Curcuma* é conhecido pelos rizomas da *C. longa*, que quando são desidratados e moídos dão origem a um condimento chamado açafrão da terra, a base do cury

indiano. Outras espécies de curcuma tem potencial ornamental conhecido desde 2004, como a *C. alismatifolia*, *C. zedoaria*, *C. amada* and *C. augustifolia* (Nair, 2013).

C. alismatifolia, também conhecida como tulipa do Siam, tem potencial para ser utilizada em canteiros, em pote ou como flor de corte. Sua flor é na verdade uma inflorescência de aparência cônica, onde as brácteas distais são verdes e as apicais podem ser rosadas, roxas ou brancas. As brácteas estão arranjasdas em forma de espiral e assim tem o aspecto semelhante ao da tulipa (Nair, 2013; Bunya-atichart et al., 2004).

Entre os principais problemas que a floricultura brasileira tem que superar está o manejo pós-colheita inadequado. Ainda faltam conhecimentos e tecnologias de colheita e pós-colheita que visem à redução de perdas, que no Brasil chega a atingir 40 % da produção, e o atraso da senescência (Dias-Tagliacozzo & Castro, 2002).

As hastes de cúrcuma tem durabilidade variando entre 7 a 21 dias (Chutichudet et al. 2010, Chutichudet and Chutichudet 2012). Esta grande variação na vida de vaso é provavelmente devida a diferentes fatores e suas combinações, como por exemplo as condições de manejo e após a colheita.

A cadeia produtiva da floricultura valoriza informações sobre o manejo pós-colheita de novas espécies e cultivares, como os tratamentos que podem ser feitos ainda na propriedade rural com soluções para hidratação e condicionamento das hastes e em nível de varejo, com a utilização de espuma floral (Clark et al., 2010; Dole et al., 2009).

Soluções de vaso contendo 8-hidroxiquinolina + sacarose, dicloroisocianurato de sódio + sacarose e somente sacarose não estenderam a vida de vaso de hastes de cúrcuma cv. Chiang Mai Pink em um estudo conduzido por Bunya-atichart e colaboradores (2004), e ainda verificaram que concentrações de etileno a partir de 0,5 ppm são prejudiciais para a pós-colheita, indicando que esta cultivar é sensível ao etileno exógeno.

A aplicação de 600 ppb 1-MCP, por 8 h e por meio de fumigação, foi benéfica para a redução da degradação de antocianinas nas brácteas de curcuma cv. Chiang Mai Pink, entretanto a vida de vaso não foi alterada (Chutichudet et al., 2010).

O uso de reguladores vegetais na pós-colheita de cúrcuma, como o ácido giberélico, apresenta resultados positivos na manutenção do peso fresco das hastes tratadas, contudo existe divergência quanto aos efeitos na vida de vaso. Kjonboon e Kanlayanarat (2005) constataram efeito positivo do ácido giberélico na vida de vaso de curcuma de corte, com o

aumento de 4 dias de durabilidade em relação ao controle e Bunya-atichart e colaboradores (2004) não verificaram diferenças na vida de vaso entre as hastes tratadas com regulador vegetal e o controle experimental.

Outro aspecto da utilização das flores é a disposição destas em espuma floral para a confecção de arranjos. Ahamad e colaboradores (2014) observaram que rosas do cultivar 'Charlotte' tem redução de 2 dias na vida de vaso se dispostas em espuma floral embebida em água deionizada e que acrescentando 'Floralife Pro Flower Food' à espuma floral, as rosas tem a mesma durabilidade que as hastes mantidas somente em água deionizada.

Capítulo 1

Anthurium andraeanum senescence in response to 6-benzylaminopurine: vase life and biochemical aspects¹

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***Anthurium andraeanum* senescence in response to 6-benzylaminopurine: vase life and biochemical aspects**

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Abstract: Proper postharvest handling is fundamental to maintain and extend vase life of cut ornamentals and positive effect of growth regulators has been reported. This research aimed to determine rather spraying or pulsing BAP performed better in keeping postharvest quality of *Anthurium andraeanum* cv. Apalai (IAC NK 130) and in which concentration (0, 37.5, 75, 150 and 300 mg L⁻¹). Vase life, fresh weight, soluble carbohydrate content, total phenolic content and polyphenol oxidase activity were determined on spathe and spadix. Spraying BAP was more effective than pulsing in extending vase life, 17.9 and 13.8 days, respectively, and in maintaining fresh weight, 93 and 76 % of initial, respectively. Spathes treated with BAP concentration below 150 mg L⁻¹ showed higher soluble carbohydrate content. Total phenolic content was higher in pulsing than in spray treatment. In spathes, TPC decreased and PPO activity increased with the increase of BAP concentration. Spraying BAP was more effective for postharvest handling of anthurium cv. Apalai than application by pulsing.

Key words: fresh weight, total phenolic content, polyphenol oxidase, spraying, pulsing

INTRODUCTION

Anthurium (*Anthurium andraeanum* Linden ex Andre) stands out from other cultivated tropical ornamental species, because of its beauty, robustness and postharvest longevity (Gantait and Mandal 2010). Global expansion of anthurium as a floriculture crop occurred with the development and launch of new varieties between 1998 and 2002 by the Agronomic Institute of Campinas (Tombolato et al. 2005) and in 2003 by the Dutch Company Anthura (Leme 2004).

Postharvest quality of flowers and ornamental plants is linked directly to environmental conditions and management during production and harvest. It is known that proper post-harvest treatment does not improve original quality, but only maintains quality and, depending on its effectiveness, can prolong shelf or vase life (Pinto 1997).

Anthurium quality can be defined as postharvest longevity or vase life, as well as physical attributes like color and spathe diameter and stem length. These characteristics are specific to the cultivar, along with field management and the use of postharvest techniques (Viradia and Singh 2004). A market survey conducted in Hawaii with 73 retail florists showed that anthurium vase life and spathe color were the deciding factors for buying, and 44 and 44 % of the florists expected a minimum vase life of 10 and 15 days, respectively (Halloran and Kuehnle 1998).

An attractive anthurium cut flower comprises a colored modified leaf, called bract or spathe and an inflorescence with over 300 spirally arranged minuscule flowers, the spadix (Croat 1988). According to Elibox and Umaharan (2008) peduncle base browning, spadix necrosis, and spathe blueing/necrosis were the only signs of senescence common to all 26 anthurium cultivars studied. To ensure the ongoing quality of anthurium flowers, Thawiang et al. (2007) recommended that postharvest treatments be used to extend vase life and delay senescence.

Senescence is strongly modulated by plant hormones, like any other stage of plant development (Skutnik et al. 2001) and plant growth regulators can be used to extend postharvest storage of plant species. It has been found that exogenous application of plant growth regulators such as gibberellins or cytokinins interferes with leaf senescence. Cut *Matthiola incana* L. stems treated with 5 or 10 mM thidiazuron delayed leaf yellowing for 30 days, for both concentrations (control: 7 days), delayed petal wilting 10 and 11 days, respectively (control: 8 days) and lengthened vase life to 10 and 11 days, respectively (control: 7 days) (Ferrante et al. 2009).

Many cytokinins effects are related to prolonging vase life of cut flowers. Tropical plants studies showed that the cytokinin response varies greatly and this variation in vase life response depends on the species, time of the year when harvest takes place, and cultivar (Paull and Chantrachit 2001). Plants treated with cytokinin can have altered sugar concentration induced by removal of sinks or phloem interruption (Crafts-Brandner et al., 1994).

In the vase life prediction equation proposed by Elibox and Umaharan (2008), carbohydrates can have a direct or indirect effect in the senescence process depending on the inclusion of green/not green anthurium cultivar in the model.

Higher phenolic content was associated with longer vase life in cut rose petals (Mwangi et al., 2003), but may have negative side effects. The phenols may account for spathe blueing/necrosis (Elibox and Umaharan 2008) and polyphenol oxidase (PPO), a copper containing enzyme, which occurs in many plants (Falguera et al. 2012), can catalyze the oxidation of phenolic substrates to the formation of unattractive brown pigments (Chisari et al. 2011).

An understanding of changing patterns in vase life, fresh weight, soluble carbohydrate content, total phenolic content and polyphenol oxidase activity will assisted in determining the best postharvest handling procedures.

The aims of this study are to test the hypothesis that 6-benzylaminopurine (BAP) will improve keeping postharvest quality of *Anthurium andraeanum* cv. Apalai (IAC NK 130) due to its effect on delaying senescence, and, if valid, to determine the optimum mode of application and concentration.

MATERIALS AND METHODS

Plant material

Cut *Anthurium andraeanum* cv. Apalai (IAC NK 130) stems were obtained from a commercial grower from Pariquera-Açú, Sao Paulo – Brazil (24.7150° S, 47.8811° W). Regional climate classification according Köpen is Af, rainy tropical, without dry season and average rainfall of the driest month above 60mm. In a ten year data series (2011-2011), averaged annual maximum and minimum temperature were 26.7°C and 17.1°C, respectively and average annual rainfall was 1,715,6 mm.

Growing environment consisted of a well-drained and aerated soil, rich in organic matter content under a 75% shade net house. Non-injured stems were cut in the morning, transported dry to the postharvest laboratory, immediately re-cut to 30 cm length upon arrival after a 3-hour trip, and placed in buckets containing tap water.



Figure 1: A-After transport, B- After 2 cm re-cut, C-30 cm standardized stem length, D-Spray treatment, E- Pulsing treatment, F- Sampling for biochemical analysis, G- Spathe, H- Spadix in falcon tube, I- Spathe in plastic bag, J- Spathe ready to be frozen.

Postharvest treatments

Anthurium inflorescences were subjected to either a 24h pulse through the stem or to a spray on the spathe and spadix until runoff with solutions containing 0 (control), 37.5, 75, 150 and 300 mg L⁻¹ 6-benzylaminopurine (Sigma-Aldrich, USA) and then stored for 20 days at 25±2°C/80±5% RH and 12 hours photoperiod with a photosynthetic photon flux of ~20 µmol m⁻² s⁻¹ provided cool-white fluorescent lamps. After treatments and during vase life evaluation, anthurium stem bases were kept in vases filled with tap water, which was renewed every two days.

Postharvest evaluation

Visual assessment of quality was performed every two days on the 30 stems, according to procedures used by Paull (1982). This appraisal consisted in scoring each anthurium inflorescence for loss of spathe gloss, spathe blueing and spadix necrosis as listed in the following tables.

Table 1. Grading scale for spadix visual condition (Paull 1982).

Score	Spadix condition
1	No spots
2	Spadix tip showing slight discoloration/darkening
3	Spadix tip showing darkening/slight flower separation
4	Less than 10% of spadix length darkened and dry
5	Spadix tip dried and necrosed in more than 10% of its lenght

Table 2. Grading scale for spathe blueing (Paull 1982).

Score	Spathe condition
1	None – fresh flower looks, no blueing
2	Slight – less than 5% blueing area
3	Moderate – 5 to 10 % blueing area
4	Severe – more than 5% blueing area

Table 3. Grading scale for spathe glossiness (Paull 1982).

Score	Spathe condition
1	No loss – high gloss stage right after harvest
2	Slightly loss – not perceivable
3	Moderate loss – slight glossiness remain
4	Severe loss – flat spathe, no glossiness and wilting signs may appear

Vase life was determined by numerating the days before a stem reached grade 3 for spadix necrosis and/or grade 4 of spathe blueing and/or grade 4 for spathe glossiness, whichever comes first.

Fresh weight was measured by weighting each stem at the same day visual evaluation was done and its variation were determined by the following formula for each evaluated day:

$$FW(\%) = \frac{W_1 * 100}{W_0}$$

FW – Fresh weight in % relative to initial weight; W_0 – initial weight (g); W_1 – weight on the evaluation day.

For biochemical analysis samples were collected every 4 days. The inflorescence was divided in spathe and spadix, placed separately into identified plastic bags, wrapped in aluminum foil, and fast frozen in liquid nitrogen. All samples were freeze grinded with help of cryogenic mill (SPEX SamplePrep 6870 Freezer/Mill® - USA); the resulting powder was collected in 15mL falcon tubes and stored at -20°C until analyzed.

Soluble carbohydrates were determined by a phenol–sulfuric acid method (Dubois et al. 1956). Previously frozen milled spathe and spadix tissues were extracted with distilled water and heated at 40°C in a water bath (Nova Etica 316 3DN, Brazil) for 30 min. After cooling to room temperature, the extracts were centrifuged (Jouan SA MR 18-12, France) at 5000 rpm for 10 min at 25 °C to remove debris and the supernatant was collected apart. Absorbance was measured at 490 nm in a spectrophotometer (BEL Photonics 2000 UV, Brazil) against a blank cell. The sugar concentration was obtained by referring to the standard glucose (Sigma-Aldrich, Brazil) graph. Total carbohydrates were expressed in mg g⁻¹ fresh weight. Determination was carried out in triplicate for each sample and the results were averaged.

Total phenolic content (TPC) was extracted and quantified by Singleton and Rossi (1965) using Folin-Ciocalteu phenol reagent (Sigma-Aldrich, Brazil). TPC of the spadix and spathe extracts was measured at 760 nm on a UV-VIS spectrophotometer (BEL Photonics 2000 UV, Brazil) against a blank cell. Results are given in gallic acid equivalents (GAE, mg g⁻¹ fresh weight). All measurements were performed in triplicate

Polyphenol oxidase (PPO) activity assay was conducted according to Campos and Silveira (2003). Spathe and spadix were grounded again in a pre-chilled mortar with polyvinylpyrrolidone-PVPP (Sigma-Aldrich, USA) and 0.05M phosphate (Sigma-Aldrich, Brazil) buffer pH 7.0, homogenate was centrifuged for 30 min at 10000 rpm / 4°C (Jouan SA MR 18-12, France). Supernatant was referred as enzyme extract. PPO activity was determined using a spectrophotometric method based on an increase rate of absorbance against a blank sample without the enzyme extract at 395 nm. Briefly, the reaction mixture contained 0.05M phosphate (Sigma-Aldrich, Brazil) buffer pH 6.0, 0.01M pyrocatechol (Sigma-Aldrich, Brazil), and the enzyme extract or distilled water for the blank. Reaction was stopped by adding HClO₄ (Sigma-Aldrich, Brazil) 6.9%. Resulting solution absorbance was measured at 395 nm in a UV-VIS spectrophotometer (BEL Photonics 2000 UV, Brazil) against a blank cell. PPO activity was expressed in enzyme activity unity (U) g⁻¹ FW min⁻¹. Determination was carried out in triplicate for each sample and the results were averaged.

Statistics

Experimental design was completed randomized arranged in split-split-plots, form of application on the main plots, BAP concentration on sub-plots and time in sub-sub-plots. Results were statistically analyzed with help of Sisvar software (Ferreira 2011), it was prepared analysis of variance and means were compared by Scot Knott's test at 0.05 significance level for qualitative data or regression for quantitative data.

RESULTS AND DISCUSSION

Spray treatment extended vase life of anthurium cv. Apalai when 37.5, 75, 150 and 300 mg L⁻¹ of BAP was applied compared with the same concentration used in the pulsing treatment (Figure 2A). The vase life averaged over all four concentration was 17.8 days for the spray treatments and 13.9 days for pulse treatments. There was no difference in vase life between application mode for the control treatments.

Studies revealed that Apalai cultivar tested for conditioning solutions containing only water (control), sucrose (50 g L⁻¹) or citric acid (0.2 g L⁻¹) had inflorescence durability of 16 days regardless used treatment (Nomura et al. 2014). Comparing our results with Nomura study there was a 1.8 extra and 2.1 less days of vase life for BAP spray and pulsing treatment, respectively.

Regression analysis of the combined factors is showed in figure 1B and comparing fitted parameter values it was found that spraying or pulsing have statistically identical vase life for both application mode control treatment. Spraying BAP was better at extending vase life than pulsing, independent of growth regulator concentration.

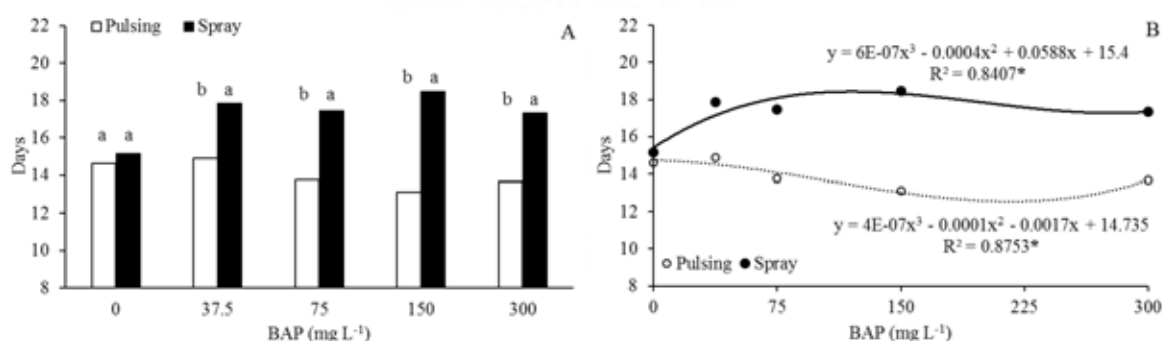


Figure 2. Vase life (days) of *Anthurium andraeanum* stems after pulsing or spraying with 6-benzylaminopurine (BAP). (A) Different letters indicate statistical difference in Scot Knott means comparison test at 5% significance level; (B) * indicate that model was statistical significant on F-test ($P < 0.05$)

Mode of application and storage time had a statistical significant interaction on the analysis of variance (Figure 3). During the first four days after treatment, there was no change in FW between pulsing and spray and after 6th day, anthurium stems pulsed with BAP had markedly higher FW loss compared to BAP sprayed stems, maintaining 73 and 93% of the initial FW on the 20th day, respectively (Figure 3). This final FW percentage rate for pulsing treatment shows greater FW loss than anthurium stems kept for 20 days at 4°C, which had a maximum loss of 19% FW (81% of initial FW) in a study from Promyou et al. (2012)

Throughout vase life, fresh weight typically declines over time, and this was seen for both postharvest treatments. However, spray treatments showed no statistical significant FW change until 8th day, while pulsing treatment FW declined after only the 4th day (Figure 3). On a study testing wax coating on anthurium, stems stored at 18°C that received wax

maintained FW close to the initial weight for 10 days (Mujaffar and Sankat 2003), a result similar to the spray treatment in this paper.

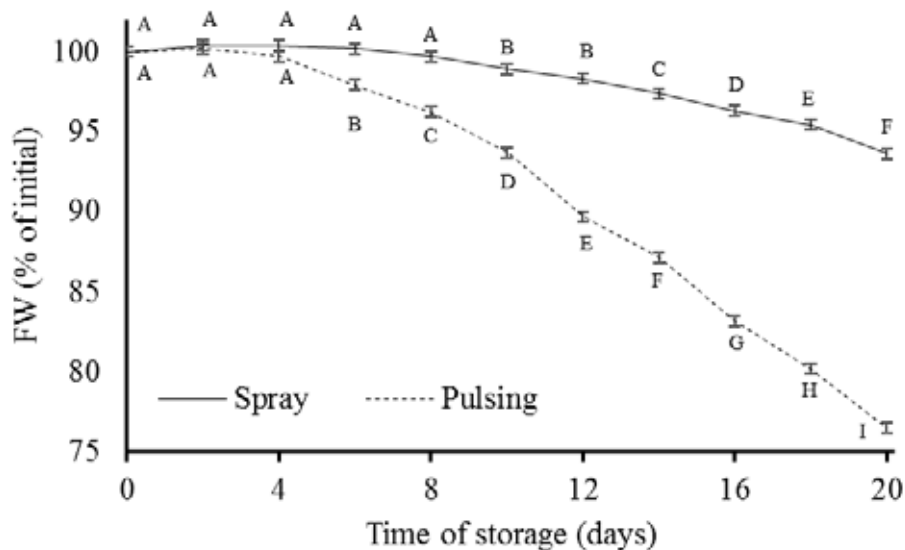


Figure 3. Fresh weight (% of initial) from the statistical significant interaction of mode of application x time of storage of *Anthurium andraeanum* stems pulsed or sprayed with 6-benzylaminopurine (BAP). Standard error bars shows difference between mode of application on each day and time of storage (days) followed by same capital letters were not different by Scot Knott's means comparison test at 5% significance level

The soluble carbohydrate content of anthurium spadix and spathe were influenced by BAP levels (Figure 4) and by mode of application versus storage time interaction ($P < 0.05$) (Table 5). Spadix tissue showed increasing soluble carbohydrate content from zero to 75 mg BAP L⁻¹, returning to levels similar to the control at 150 mg BAP L⁻¹ and rising again at 300 mg BAP L⁻¹, according to the cubic fitted model. On the spathe, soluble carbohydrate showed a slight decrease in content with the increase of BAP level, according to the quadratic fitted model. Therefore, BAP concentration lower than 150 mg L⁻¹ presented higher soluble carbohydrate content on spathe, whereas on spadix BAP levels had little impact on carbohydrate content.

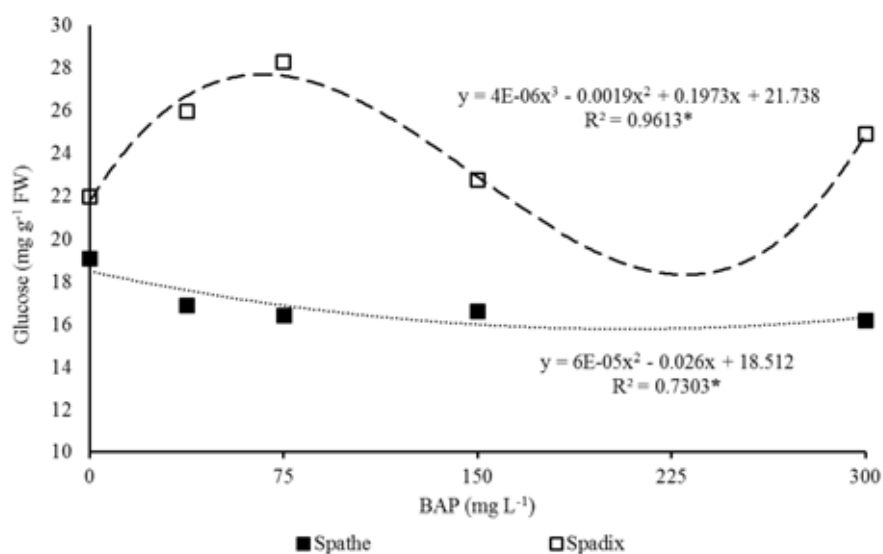


Figure 4. Fitted models for soluble carbohydrate content from spadix and spathe of *Anthurium andraeanum* stems pulsed or sprayed with 6-benzylaminopurine (BAP).

Pulsing BAP treatment showed a constant raise in carbohydrate level after 4th day on spadix and after 8th day on spathe compared with spray treatment. Storage time by application mode shows a constant increase in soluble carbohydrate throughout vase life on spadix and after 12th day on spathe for pulsing treatment and increasing soluble carbohydrate content until 8th day on spadix and constant levels on spathe for spraying treatment (Table 5).

During anthurium senescence, Paull et al. (1985) observed that carbohydrate levels remained constant, which was the case on the spathes of spray treatment. Elevated soluble carbohydrate content does not seem to contribute to anthurium vase life, not even to keep water balance as pulsing treatment presented higher carbohydrate levels with greater fresh weight loss and shorter vase life compared to spray treatment.

Rise in carbohydrate levels was more evident in spadix than on spathe. Cytokinin presence in reproductive structures might extend the tissue sink, improving movement of sugars, amino acids, and other solutes from mature tissues (Salisbury and Ross 1991). Cut peony (*Paeonia lactiflora* Pall.) stems also show an increase in total sugars during the first 2/3 of its vase life, which was due to starch breakdown (Walton et al. 2010).

Table 5. Soluble carbohydrate content (mg glucose g⁻¹ fresh weight) from spadix and spathe of *Anthurium andraeanum* stems pulsed for 24h or sprayed until runoff with 0, 37.5, 75, 150 and 300 mg L⁻¹ of 6-benzylaminopurine (BAP) and stored for 20 days at 20±2°C/80±5% RH.

Day ¹	Soluble carbohydrate (mg g ⁻¹ FW)			
	Spadix ²		Spathe ³	
	Pulsing	Spray	Pulsing	Spray
0	18.6 Da	17.4 Ba	16.3 Ca	15.9 Aa
4	20.2 Da	16.7 Bb	16.8 Ca	16.4 Aa
8	23.5 Ca	17.5 Bb	17.1 Ca	15.6 Ab
12	27.5 Ba	20.2 Ab	18.1 Ca	16.0 Ab
16	34.3 Aa	22.9 Ab	19.5 Ba	16.1 Ab
20	35.9 Aa	21.0 Ab	22.1 Aa	15.4 Ab

¹Means followed by same capital letters on the column are not different by Scott Knott's means comparison test at 5 % significance level; ^{2,3}Means followed by same low case letters on the row are not different by Scott Knott's means comparison test at 5 % significance level; ⁴MD-Mode of application.

Total phenolic content of anthurium spadix and spathe were influenced by BAP levels (Figure 5) and by mode of application versus storage time interaction ($P < 0.05$) (Table 6). For spadix tissue decreasing total phenolic content occurred with increasing BAP levels, according to the linear fitted model. For the spathe, a quadratic model was fitted and TPC had minimum value around 150 mg L⁻¹.

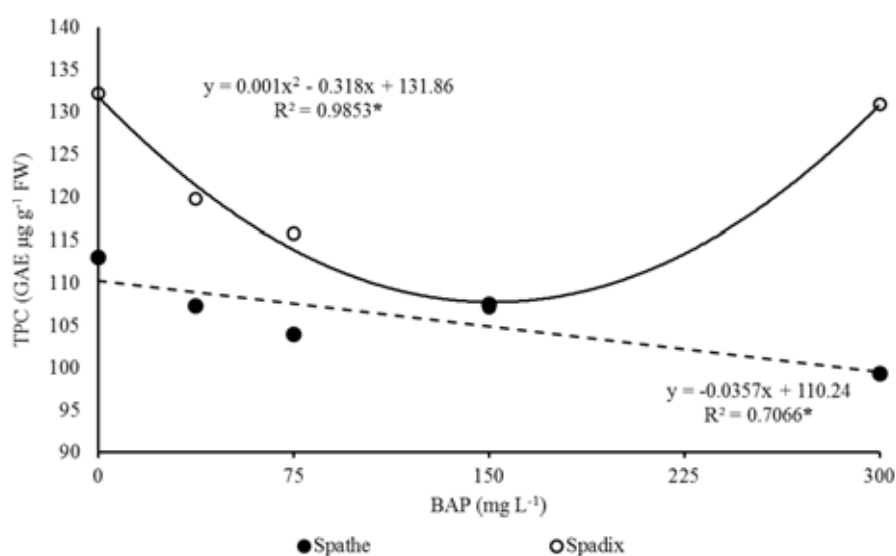


Figure 5. Fitted models for total phenolic content (galic acid equivalent GAE mg g⁻¹ FW) from spadix and spathe of *Anthurium andraeanum* stems pulsed or sprayed with 6-benzylaminopurine (BAP). *Regression with statistical significant parameters after F-test (P<0.05).

Pulsing treatment resulted in higher total phenolic content in all evaluated days on spadix and only on the 20th day on spathe compared to spray treatment (Table 6). Total phenolic content on spadix from pulsing treatment had a tendency to increase towards 20th day and peak on 8th and 12th day for spray treatment. However, for spathe, TPC increased after 16th day on pulsing treatment and remained unchanged on spraying treatment.

Phenolics show an important part in antioxidant protection by the plant (Haslaam 1998) and senescence conditions generally result in an increase in antioxidant levels as they represent a key defense strategy against oxidative stress (Cavaiuolo et al. 2013).

In anthurium phenolic compounds concentration increases on anthurium senescence (Paull et al. 1985) similar to our results from pulsing treatment with increasing TPC and shorter vase life. Total phenolic content of spray treatment increased only on the spadix and close to the end of the vase life.

Table 6. Total phenolic content (gallic acid equivalent GAE mg g⁻¹ FW) from spadix and spathe of *Anthurium andraeanum* stems pulsed for 24h or sprayed until runoff with 0, 37.5, 75, 150 and 300 mg L⁻¹ of 6-benzylaminopurine (BAP) and stored for 20 days at 20 ± 2 °C / 80 ± 5 % RH.

Day ¹	Total phenolic content (GAE mg g ⁻¹ FW)			
	Spadix ²		Spathe ³	
	Pulsing	Spray	Pulsing	Spray
0	119.4 Ca	85.8 Db	105.3 Ba	101.3 Aa
4	126.3 Ca	95.3 Cb	99.4 Ba	95.6 Aa
8	130.8 Ba	109.9 Ab	107.6 Ba	104.8 Aa
12	122.2 Ca	112.2 Ab	101.4 Ba	91.4 Aa
16	135.0 Ba	101.7 Bb	121.2 Aa	109.8 Aa
20	140.5 Aa	103.6 Bb	134.8 Aa	106.5 Ab

¹Means followed by same capital letters on the column are not different by Scott Knott's means comparison test at 5 % significance level; ^{2,3}Means followed by same low case letters on the row are not different by Scott Knott's means comparison test at 5 % significance level; ⁴MD-Mode of application.

Polyphenol oxidase activity of anthurium spathe was influenced by BAP levels (Figure 6). Spathe tissue had increasing levels of PPO activity when more than 150 mg BAP L⁻¹ was applied in anthurium stems, according to the quadratic fitted model. Spadix enzyme activity remained constant regardless BAP concentration applied.

Phenolic content and enzyme activity outcomes on the spathe were correlated. While spadix PPO activity was constant, on the spathe enzyme activity increased with increasing BAP concentration while TPC decreased until 150 mg L⁻¹, indicating that TPC drop was due to increased enzyme activity.

BAP levels greater than 150 mg L⁻¹ induced higher PPO activity, which combined with high phenolic content can stimulate browning reaction, resulting in the formation of quinone and subsequently polymerization leading to production of brown pigments (Dubravina et al., 2005).

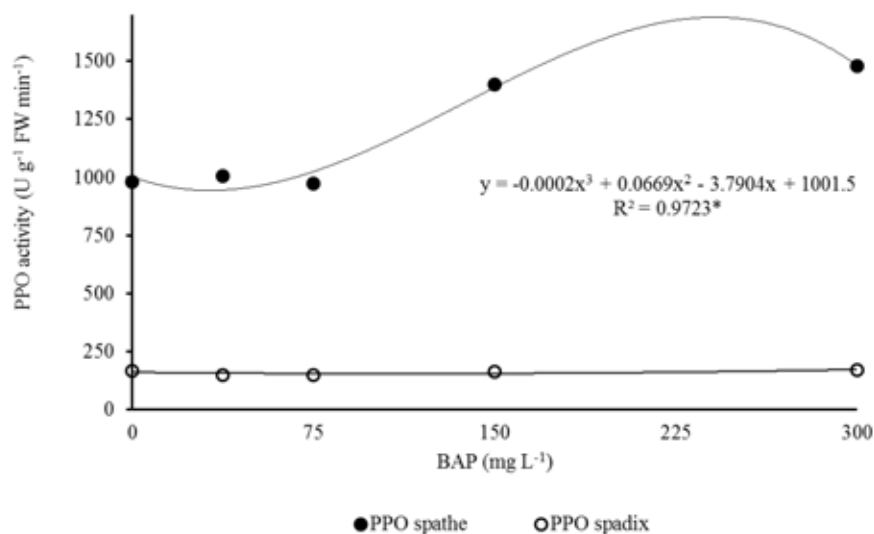


Figure 6: Polyphenol oxidase activity ($\text{U g}^{-1} \text{FW min}^{-1}$) of spathe (fitted model) and spadix of *Anthurium andraeanum* pulsed and sprayed with 6-benzylaminopurine (BAP). *Regression with statistical significant parameters after F-test ($P < 0.05$).

Mode of application versus storage time interaction ($P < 0.05$) was significant for both spadix and spathe (Table 7). On spadix PPO activity decreased for both treatments. Spathe tissue showed a trend of decreasing PPO activity during vase life evaluation on spraying treatment except for an activity peak on 12th day and pulsing treatment exhibited higher PPO activity on days 0, 12 and even higher on 20th day compared to days 4, 8 and 16.

Anthurium spathe is greatly affected through darkening reaction, visualized on senescent tissue by blueing and PPO activity was markedly higher in this tissue. Senescence advanced more rapidly in pulsing treated anthurium and according to Benjawan et al. (2008), a loss of cellular compartmentalization enables enzyme and substrate contact, resulting in enzymatic browning.

Table 7. Polyphenol oxidase (PPO) activity (enzyme activity unity U g⁻¹ FW min⁻¹) from spadix and spathe of *Anthurium andraeanum* stems pulsed for 24h or sprayed until runoff with 0, 37.5, 75, 150 and 300 mg L⁻¹ of 6-benzylaminopurine (BAP) and stored for 20 days at 20 ± 2 °C / 80 ± 5 % RH.

Day ¹	PPO activity (U g ⁻¹ FW min ⁻¹)			
	Spadix ²		Spathe ³	
	Pulsing	Spray	Pulsing	Spray
0	199 Aa	200 Aa	1404 Ba	1329 Aa
4	164 Bb	197 Aa	1174 Ca	1037 Bb
8	135 Cb	178 Ba	1065 Ca	1063 Ba
12	125 Cb	192 Aa	1316 Ba	1196 Aa
16	137 Cb	172 Ba	1174 Ca	897 Cb
20	144 Ca	153 Ba	1575 Aa	909 Cb

¹Means followed by same capital letters on the column are not different by Scott Knott's means comparison test at 5 % significance level; ^{2,3}Means followed by same low case letters on the row are not different by Scott Knott's means comparison test at 5 % significance level; ⁴MD-Mode of application.

To extend the vase life of anthurium cv. Apalai it is recommended the application of BAP by spraying at concentrations below 150 mg L⁻¹ due to lower activity of PPO in these doses and therefore less possibility of darkening the spathe. Despite the high concentration of phenolic compounds with low concentrations of BAP (below 150 mg L⁻¹), the activity of PPO was not changed and thus no blackening of the spathe was observed. Also, at doses below 150 mg L⁻¹, higher levels of carbohydrates were found in the spathe, which could favor the maintenance of respiration and a positive water balance due to the presence of solutes.

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Capítulo 2

***Curcuma alismatifolia* vase life²**

² Artigo nas normas do International Journal of Environmental Science and Technology

Curcuma alismatifolia vase life

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Abstract: Cut curcuma stem have a reported vase life of 7 to 21 days and this difference in vase life is probably due to different factors and combination of factors such as growing conditions and postharvest treatments Specialty cut flower industry need key postharvest information for new species and cultivars to be able to effectively market the flowers. The objectives of this study was to evaluate the effect of a commercial hydrator and holding solution, floral foam, silver thiosulphate (STS) and a commercial growth regulator formulation on the postharvest handling of *C. alismatifolia* cultivars. Control treatment (deionized water) had better vase life than combinations of commercial hydrator for 4 h and commercial holding solution for 44h. Floral foam reduced vase life to 17 days form 23 days for the control treatment. STS did not improved vase life, nor did ethylene reduce it. Growth regulator (Fresco[®]) had a positive effect on keeping fresh weight parameter, but further studies are necessary. The curcuma cultivars tested were not affected by vase solutions and had an average vase life in deionized water of 21 days.

Key words: siam tulip, Chiang Mai Pink, ethylene, postharvest, floral foam, STS

INTRODUCTION

The genus *Curcuma* is well known due to the culinary use of *C. longa*, whose rhizomes are dried and powdered to produce a condiment called turmeric, base of curry spice. Other *Curcuma* species like *C. alismatifolia*, *C. zedoaria*, *C. amada* and *C. augustifolia* have ornamental potential (Prabhakaran Nair 2013).

C. alismatifolia, also called Siam tulip, is native to Southeast Asia and has potential to be used as a bed plant, potted or as cut flower. Its flower is actually an inflorescence with cone-like appearance where the distal bracts are green and apical ones can be pink, purple or

white and are spirally arranged and closely overlapped, giving a tulip-like appearance (Prabhakaran Nair 2013, Bunya-atichart et al. 2004).

Cut curcuma stem have a reported vase life of 7 to 21 days (Chutichudet et al. 2010, Chutichudet and Chutichudet 2012). This enormous fluctuation in vase life is probably due to various factors and combination of factors such as growing conditions and postharvest treatments.

Specialty cut flower industry values key postharvest information for new species and cultivars, such as treatments that can be done at wholesaler level with commercially available hydrator and/or holding solutions and at retailer level with the use of floral foam. (Clark et al., 2010, Dole et al. 2009)

Curcuma cv. Chiang Mai Pink stems were ethylene sensitive and did not responded well to 8-HQS + sucrose, DICA + sucrose and sucrose alone in the vase solution (Bunya-atichart et al. 2004). 1-MCP fumigation for 8h at 600 ppb controlled anthocyanin degradation, but did not extend vase life of *Curcuma* cv. Chiang Mai Pink stems (Chutichudet et al. 2010). Gibberellic acid had a great impact on maintaining fresh weight when applied after harvest, but studies diverged on its effect on vase life, either positive (Kjonboon and Kanlayanarat 2005) or neutral (Bunya-atichart et al. 2004).

The objective of this study was to evaluate the effect of a commercial hydrator and holding solutions, floral foam, silver thiosulphate and a commercial growth regulator formulation on the postharvest performance of cut *C. alismatifolia* flowers from four cultivars.

MATERIALS AND METHODS

Four *Curcuma alismatifolia* cultivars were grown in Raleigh/NC: Chiang Mai Pink 943005, 9472229 and 8171141. Rhizomes provided by a Thailand breeding company were planted in lily crates 55.5x36.5x22.5 cm, filled with a commercial peat-based substrate (4P Fafard Conrad Fafard Inc. Agawam MA) on 6 June 2013 and kept in a glasshouse with temperature control set to 25°C. On the first two weeks substrate was kept moist with tap water only and after the rhizomes started to sprout, liquid fertilization with 175 ppm N (20-10-20) was provided when necessary, approximately twice a week. Two months after planting, enough flowers were produced to start experiments.

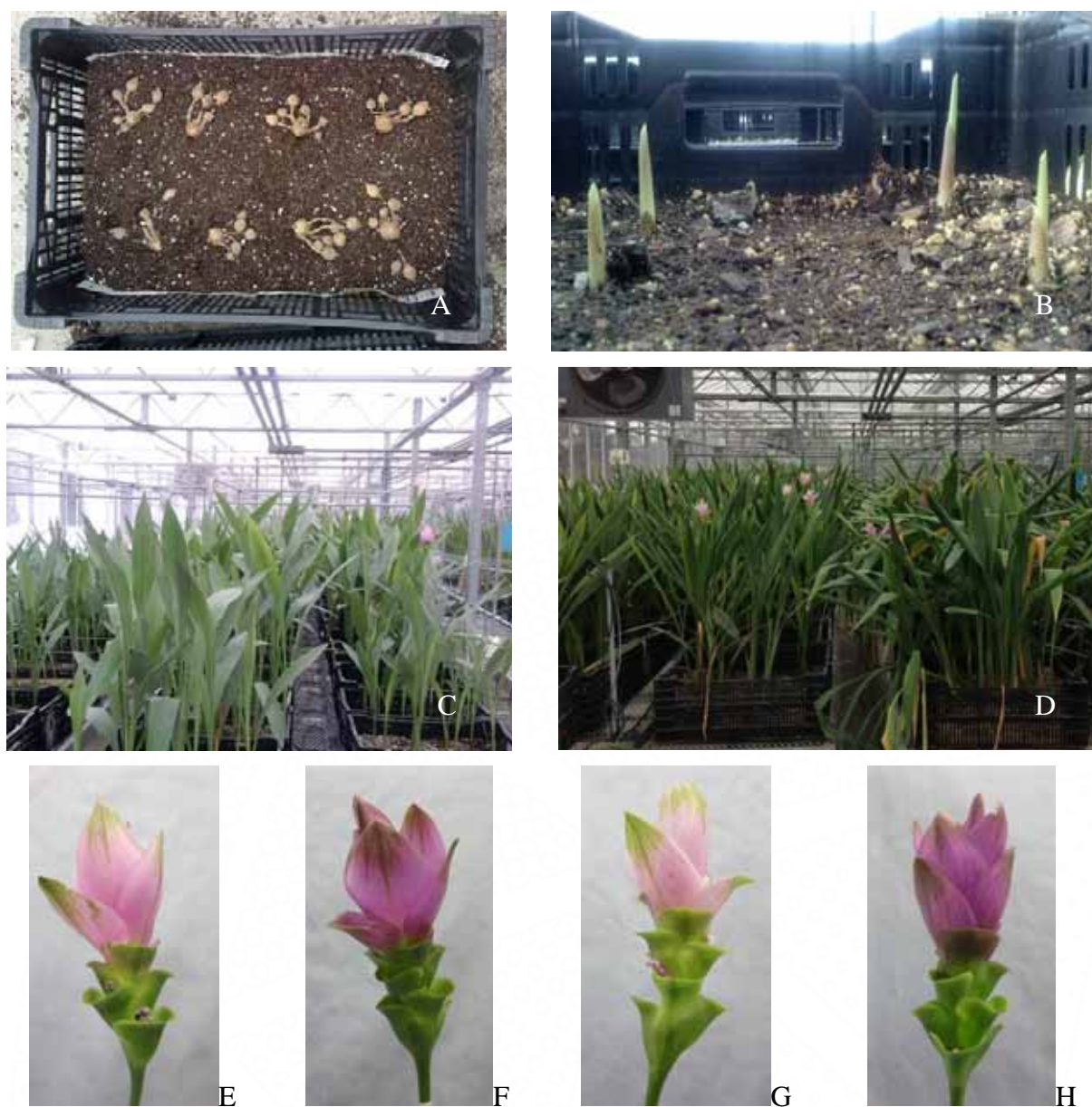


Figure 1: A- Planting, B- Sprouting, C- 2 months old, D- 5 months old, E- Chiang Mai Pink, F- 8171141, G- 943005, H- 9472229

Wholesaler treatments: After harvest stems were recut to 50 cm, divided into two groups, and treated with either deionized water (DI) or Chrysal Professional RVB Hydrating Solution (Chrysal Americas Miami FL) (hydrator) at 8 mL L^{-1} for 4 h. Then one group of flowers from each solution was placed in either deionized water (DI) or Chrysal Professional no. 2 Processing Solution (Chrysal Americas Miami FL) (holding) at 10 mL L^{-1} for 44 h. Subsequently, stems were set in jars containing 500 mL of deionized water until terminated.

Retailer treatments: After harvest stems were recut to 50 cm, placed in vases with or without floral foam and either deionized water or Chrysal Professional no. 2 Processing Solution (Chrysal Americas Miami FL) (holding) at 10 mL L⁻¹ until terminated.

Ethylene sensitivity: After harvest stems were recut to 50 cm treated either with deionized water or Chrysal AVB (Chrysal Americas Miami FL) at 2 mL L⁻¹) for 4h prior to 15h ethylene treatment in DI water at 0 or 1 ppm ethylene inside sealed drums with air forced circulation at 20°C.

Fresco[®] treatment: After harvest stems were recut to 50 cm, treated with Fresco[®] (Fine Americas Inc) solutions at 0, 0.5, 1 and 2 ppm for 15h, and then placed in jars containing 500 mL of deionized water until terminated.

Each treatment had 10 replicates of one stem per vase and vases were organized on benches in a completely randomized design in the postharvest evaluation room, which was held at 20 ± 2 °C with 40–60% relative humidity and a 12-h photoperiod provided by cool-white fluorescent lamps. The lamps provided a photosynthetic photon flux of ~20 µmol m⁻² s⁻¹ as measured at bench level with a 1078 QMSW Quantum meter (Apogee Instruments Inc. Logan UT).

Vase life was determined by numerating the days before the pink bracts darkened, browned or wilted unacceptably or green bracts turned yellow.

Not all cultivars were tested in all experiments due to insufficient flower production.

RESULTS AND DISCUSSION

Wholesaler standard treatment results showed a significant interaction between cultivar x treatment for vase life parameter (Table 1). Vase life was not affected by these treatments in all cultivars, except for 9472229, which had higher vase life on the control treatment (DI/DI).

Considering that using deionized water is the best postharvest solution for wholesalers, cultivars Chiang Mai Pink, 943005 and 9472229 had a longer vase life than cv. 8171141 (Table 1). In a study with vase solutions containing 8-HQC and DICA associated with sucrose and sucrose alone also showed no positive effect on vase life of *Curcuma alismatifolia* cv. Chiang Mai Pink (Bunya-atichart et al., 2004).

Lower fresh weight loss occurred when the commercial hydrator solution for 4h was followed by the commercial holding solution for 44h than the other three treatments, but this

positive effect did not increased vase life (Table 1). Cultivar Chiang Mai Pink maintained higher fresh weight than 8171141; 943005 and 9472229 had the highest fresh weight loss among the four cultivars. Chiang Mai Pink had greater water uptake than the other three cultivars.

Table 1. Vase life (days), fresh weight variation (% of initial), and water uptake (mL day⁻¹) of *Curcuma alismatifolia* inflorescences treated either with deionized water (DI) or Chrysal hydration solution (H) for 4 hours then placed in deionized water (DI) or Chrysal holding solution (P) for 44h and followed by transfer to jars with 500 mL of deionized water until termination.

		Vase life (days)			
Cultivar	Treatment				
	DI/DI	DI/P	H/DI	H/P	
Chiang	24.5 Aa	22.3 Aa	23.8 Aa	23.3 Aa	
943005	22.2 Aab	19.6 Aab	19.0 Ab	20.3 Aab	
9472229	22.3 Aab	15.3 ABb	18.4 BCb	13.5 Cc	
8171141	19.4 Ab	19.4 Aab	17.0 Ab	16.2 Abc	
		Fresh weigh (% of initial)			
Treatment	DI/DI	DI/P	H/DI	H/P	
	80.3 B	82.2 B	79.8 B	87.2 A	
Cultivars	Chiang	943005	9472229	8171141	
	88.7 A	78.5 C	78.6 C	83.7 B	
		Water uptatke (mL day ⁻¹)			
Cultivars	Chiang	943005	9472229	8171141	
	8.0 A	7.8 B	7.2 B	7.8 B	

*Means followed by different capital letters were statistically different ($p < 0.05$) within the line and by different lower case letters within the column.

Placing curcuma flowers in floral foam or keeping it continuously in commercial holding solution reduced vase life an average of 5.6 days compared to stems kept in deionized water only (Table 2). Chiang Mai Pink had a greater vase life than the other two tested

cultivars for retailer treatment. Floral foam was also not recommended for postharvest handling of cut rose stems (Ahamad et al., 2014).

Retailer treatment showed a significant interaction between cultivar x treatment for fresh weight parameter and stems placed in floral foam with holding solution treatment showed lower fresh weight loss for cv. Chiang Mai Pink and 943005 and did not differ among treatments for cv. 8171141. Cultivars had statically similar fresh weight loss within treatments. Due to minus six days in vase life it was expected that this treatment showed less fresh weight loss due to less time to wilt.

Table 2. Vase life (days) and fresh weight variation (% of initial) of *Curcuma alismatifolia* inflorescences kept in deionized water (DI) or holding solution (H) and in jars with (F) or without (NF) floral foam until visual senescence symptoms appeared.

		Vase life (days)			
Treatment		DI/NF	DI/F	H/NF	H/F
			23.0 A	17.8 B	18.1 B
Cultivars	Chiang		943005	8171141	
		21.3 A	16.9 B	18.0 B	
		Fresh weight variation (%)			
Cultivar	Treatment				
	DI/NF	DI/F	H/NF	H/F	
Chiang	84.2 Ba	81.1 BCa	73.9 Ca	94.1 Aa	
943005	76.2 Bb	78.7 Ba	78.6 Ba	87.2 Aab	
8171141	82.3 Aab	78.8 Aa	75.2 Aa	83.0 Aa	

*Means followed by different capital letters were statistically different ($p < 0.05$) within the line and by different lower case letters within the column.

Chiang Mai Pink and 8171141 curcuma stems did not benefit with anti-ethylene treatment (STS) nor presented ethylene sensitivity. Vase life were 25.5 and 17.3 days, respectively. AOA did not reduced bract browning (Bunya-atichart et al., 2004) and 1-MCP was not effective in extending vase life (Chutichudet et al. 2010) of *C. alismatifolia* cv Chiang Mai Pink.

Ethylene sensitivity was reported for cultivar Chiang Mai Pink from concentration as low as 0.5 ppm (Bunya-atichart et al., 2004), which disagrees with results obtained in this

study where control, control + ethylene (1ppm), STS and STS + ethylene treatments were statistically similar. With high ACC oxidase gene expression right after harvesting in petals and bracts of *C. alismatifolia* cv. Chiang Mai Pink, suggesting involvement in vase life (Mahadatanapuk et al. 2010), we recommend further studies to be performed in the same tested cultivar and North Carolina growing conditions.

Treating Chiang Mai Pink stems with Fresco® did not influenced vase life nor water uptake and concentrations higher than 0.5 ppm increased fresh weight in approximately 10% compared to control treatment (Figure 2). Similar results were obtained by Bunya-atichart et al. (2004) with application of GA₃ at 50 and 100 ppm.

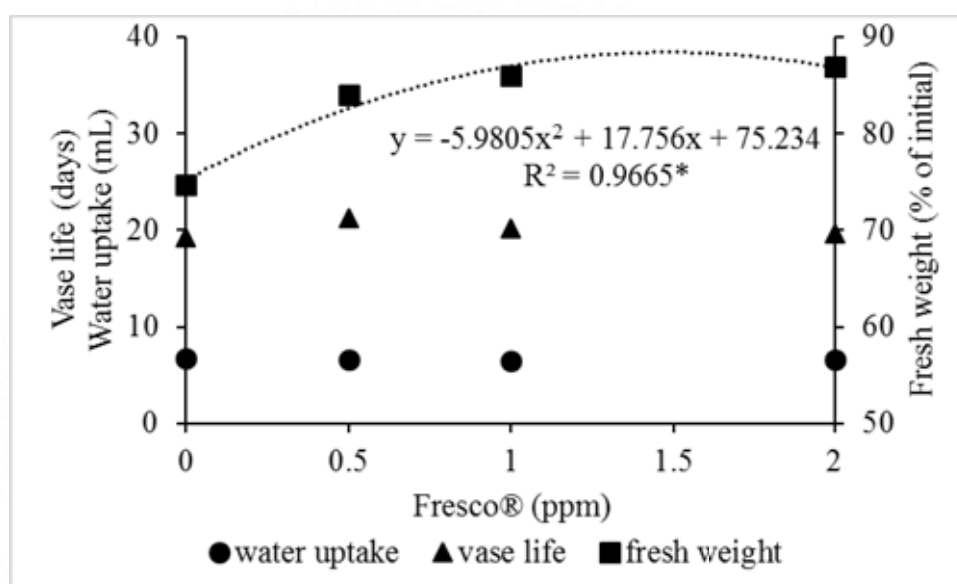


Figure 2. Vase life (days), fresh weigh variation (%), and water uptake (mL day⁻¹) of *Curcuma alismatifolia* inflorescences treated with Fresco®.

In summary, since the overall vase life of curcuma stems was good, these results mean that curcuma appears to be a durable flower that is not affected by vase solutions. The exception is that curcuma vase life is reduced with the use of floral foam.

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