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Influence of 1-MCP Fumigation on Flowering Weight Loss, Water Uptake, Longevity, Anthocyanin Content and Colour of Patumma (*Curcuma alismatifolia*) cv. Chiang Mai Pink

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ABSTRACT

Patumma is one of the most popular exported cut flowers in Thailand due to its attractive large pink bracts. Its export value, however is limited because of its poor vase life. The objective of this research was to extend patumma's shelf life by using a substance against ethylene action, 1-Methylcyclopropene (1-MCP). The experiment was arranged in a Factorial in Completely Randomized Design, composed of two factors : 1-MCP concentration at three levels (0, 100 and 300 ppb) with period of fumigation at two levels (12 and 15 h) in a hermetically sealed plastic bucket (50 L) at 20°C. Afterwards, the treated and untreated flower stems were dipped in a plastic bottle filled with distilled water and stored in ambient temperature (27°C, 91% RH). Weight loss of flowering stalk, water uptake by flowering stem, vase life, anthocyanin content and bract colour were recorded every other day at ambient temperature. The results showed that flowers treated with 300 ppb of 1-MCP for 15 h had the least weight loss of the flowering stem and preserved the highest anthocyanin content at 8 DAV. For water uptake by the flowering stem, flowers treated with 100 ppb of 1-MCP for 12 h gave the highest water uptake from six to ten days after vase life (DAV), while the maximal vase life (10.25 days) of flowers treated with 100 ppb of 1-MCP for 12 h was observed. For bract colour, the results showed that treatment with 100 ppb of 1-MCP for 15 h gave the maximal L* and a* values at 12 DAV.

Key words: *Curcuma alismatifolia*, 1-MCP fumigation, vase life, anthocyanin content, bract colour

INTRODUCTION

Patumma (*Curcuma alismatifolia*), or Siam Tulip, is an annual monocotyledon crop which is considered a perennial like ginger in the family of Zingiberaceae. This plant is widely grown in the warm and wet climate of Thailand where no less than 30 species have been found. *Curcuma alismatifolia* is regarded as an appealing local ornamental plant and a popular cut flower with high popular commercial demand. Patumma typically form a lotus-like structure, containing a small flower bud and open flower surrounded by a large attractive bright pink bract (Olarn *et al*., 2007). Olarn *et al*. (2007) reported that after the flower was cut from its plant, the display life is relatively short at only seven days. Bunya-Atichart *et al*. (2004) reported that the end of vase life of the patumma flower is partially determined by a browning appearance on the flowers bracts which causes rapid loss of their attractive colour appearance and limits the length of their

postharvest life. They also indicated that the shortened vase life of *Curcuma alismatifolia* var. Chiang Mai Pink may be related to ethylene. Ethylene is a plant hormone that accelerates the aging process leading to a shortened vase life in several flowers (Woltering and Van Doorn, 1988; Van Doorn, 2001; Serek *et al*., 2006). The compound 1-methylcyclopropene (1-MCP) has been found to be a very potent inhibitor of several ethylene-dependent processes in cutflowers. It prolongs the display life in commercial use (Feng *et al*., 2000) by competing with ethylene for the binding site on the ethylene receptor in plant tissue and controls ethylene biosynthesis and ethylene action (Sisler and Serek, 1997; De Wild *et al*., 1999; Muller *et al*., 2000; Mullins *et al*., 2000). Chutichudet *et al*. (2010a) indicated that 1-MCP fumigation for 8 h at high concentration of 600 ppb had the effect of lowering the flowering weight but not extending the vase life of the patumma flower cv. Chiang Mai Pink. This may be due to 1-MCP treatment at high concentrations of 600 and 900 ppb imposing a stress on the tissue of the flower. In an effort to extend the vase life of the patumma flower, they suggested the use of 1-MCP at a concentration lower than 600 ppb with a longer fumigation period. Furthermore, Chutichudet *et al*. (2010b) found that the Siam Tulip flowering stems in the treated group responded positively to 1-MCP application at 300 ppb for 8 h by promoting the tulip's quality characteristics of high water uptake, best retention of anthocyanin content and low browning appearance during ambient storage compared to the untreated control group. However, 1-MCP had no effect in extending the postharvest life of patumma or the Siam tulip flowers. At the present time, not much information is available regarding the use of 1-MCP to extend the postharvest life and delay the senescence processes in the patumma flower. Therefore, there is still a need to experiment and study various concentrations of 1-MCP application and longer exposure periods of this substance in order to evaluate its ability as a postharvest tool for extending the potential vase life and regulating the quality characteristics of the patumma flower. The objectives of this study were to determine the efficacy of 1-MCP treatments at various concentrations and fumigation durations to evaluate the effects of 1-MCP in prolonging the post harvest life and maintain the flower's qualities after harvesting.

MATERIALS AND METHODS

Patumma flowers (*Curcuma alismatifolia*) cv. Chiang Mai Pink were harvested at the commercial stage from a commercial garden in Chiang Mai in October 2009. Each flower was wrapped with a foam sheath and packed carefully in a fiberboard carton then transported in an air-conditioned vehicle to Mahasarakham University. During transport, buckets containing stems were covered with a plastic film shroud to minimize moisture loss. After they arrived at the laboratory, the flowers were selected again for uniformity of size, shape, initial bract colour and freedom from external damage before being placed into chambers for fumigating with 1-MCP. The stem end of each flower was recut with stainless steel scissors into 30 cm in length. The experiment was carried out from June to August 2009 at the laboratory of the Division of Agricultural Technology, Faculty of Technology, Mahasarakham University, in the Northeast of Thailand. A Factorial in Completely Randomized Design was arranged and composed of two factors: concentration of 1-MCP three levels (0, 100 and 300 ppb) with two periods of fumigation time (12 and 15 h). Each treatment was carried out in ten replicates, one flower per replication. All treatments were taken in sealed 50 L plastic buckets of 50 L capacity containing distilled water and exposed to different concentrations of 1-MCP (0, 100 and 300 ppb) with two periods of time (12 and 15 h) at the storage temperature of 20°C. While, control flowers were sealed in identical chambers without added 1-MCP and maintained under identical storage conditions. Following the treatments, each flowering stems was stood in the 500 mL plastic bottle containing distilled water and kept at ambient temperature at 27°C and 91% Relative Humidity (RH). The following

determinations were assessed every other day for assessments of (1) weight loss of the flowering stalk was calculated as the percentage of the initial weight (%) (2) water uptake by the flowering stalk was measured as mL day^{-1} (3) vase life (days) was judged to have terminated when 30% of the flowers had withered. (4) Total anthocyanin content was determined according to the method of Ranganna (1997) that compared with absorbance value at wavelength of 535 nm by the use of spectrophotometer model V-325-XS, from China. Total anthocyanin content was expressed as mg per 100 g fresh weight. (5) Bract colour was measured by using a Hunter Lab Model No. 45/0-L, Serial No. 7092, USA. CIE colour values L^* (black = -100 and white = +100), a^* (redness) (- = green and + = red) and b^* (yellowness) (- = blue and + = yellow) were measured to describe the colour of flower's bract. The collected data were statistically analyzed using the SPSS Computer Program, Version 6 (SPSS, 1999).

RESULTS AND DISCUSSION

After exposure with different concentrations of 1-MCP (0, 100 and 300 ppb) for various exposure periods (12 and 15 h), samples were then kept in plastic bottle containing distilled water and stored at ambient temperature. The recorded data composed of:

Flowering stalk weight: All patumma flowers decreased their weight as storage time prolonged. Weight loss of flowering stalk was greatly affected by 1-MCP treatments. Untreated control flowers exhibited a sharp decline in weight loss of the flowering stalk through vase life as compared to 1-MCP-treated flowers, except in the last 12 DAV. The minimum weight loss of flowers treated with 1-MCP at 300 ppb for 15 h was observed by 39.47% at 10 DAV (Table 1).

Table 1: Weight loss of patumma flowering stalk during vase life

	Weight loss (%) at DAV					
Factors	2	4	6	8	10	12
Conc. (ppb)						
0	9.31a	24.80a	34.42a	39.24a	44.18a	45.12
100	6.59b	22.41b	32.23b	33.32b	39.72b	42.47
300	4.44c	20.09c	28.83c	33.93b	39.90b	43.68
F-test	**	**	**	**	**	ns
CV (%)	8.92	6.23	2.27	8.86	4.77	3.39
LSD	0.3716	0.6651	0.7707	1.0796	0.9983	1.0588
Time (h)						
12	7.42a	22.23	32.17	36.40	41.70	44.33
15	6.07b	22.66	31.52	35.95	41.44	43.07
F-test	**	ns	ns	ns	ns	ns
CV (%)	6.17	7.59	2.40	2.34	5.60	3.48
Conc.×Time						
0 ppb 12 h	10.90a	24.96a	33.95ab	38.92a	43.93ab	45.46
0 ppb 15 h	7.75b	24.64ab	34.93a	39.92a	44.48a	44.37
100 ppb 12 h	7.41b	22.72abc	33.51ab	32.79b	39.39c	42.43
100 ppb 15 h	5.76c	22.16bc	31.02bc	34.00b	40.15bc	42.52
300 ppb 12 h	4.21d	19.15d	29.13c	34.52b	40.35bc	44.54
300 ppb 15 h	4.67cd	21.09cd	28.49c	33.38b	39.47c	42.47
F-test	**	**	**	**	*	ns
CV (%)	4.98	6.31	2.26	9.03	5.02	3.54
LSD	0.5050	0.9459	1.0901	1.5701	1.4521	1.5592

Letters within columns indicate least significant differences (LSD), at **p = 0.01, *p = 0.05, ns: Non significant

Table 2: Water uptake by flowering stalk of patumma during vase life

	Water uptake (mL) at DAV					
Factors	2	4	6	8	10	12
Conc. (ppb)						
0	3.00b	2.64c	2.91c	2.41b	1.95b	2.22b
100	3.19ab	3.05b	4.95a	3.13a	2.53a	2.69a
300	3.46a	3.80a	4.28b	2.57b	1.95b	2.86a
F-test	*	**	**	**	**	**
CV (%)	3.19	3.36	4.67	4.91	4.22	3.42
LSD	0.1194	0.1074	0.2065	0.1366	0.1123	0.1586
Time (h)						
12	3.12	3.34a	4.00	2.82	2.08	2.37b
15	3.32	2.99b	4.09	2.59	2.21	2.77a
F-test	ns	*	ns	ns	ns	*
CV (%)	3.50	3.43	5.21	4.05	4.84	3.14
Conc.×Time						
0 ppb 12 h	2.97b	2.51c	2.72c	2.30b	1.90cd	1.84b
0 ppb 15 h	3.05b	2.71c	3.06c	2.51b	2.00bcd	2.89a
100 ppb 12 h	3.30b	3.50b	5.85a	3.10a	2.68a	2.88a
100 ppb 15 h	3.08b	2.60c	4.05b	3.15a	2.40ab	2.47a
300 ppb 12 h	3.10b	3.95a	3.40bc	3.05a	1.71d	2.83a
300 ppb 15 h	3.83a	3.65ab	5.15a	2.05b	2.23bc	2.89a
F-test	**	**	**	**	**	**
CV (%)	3.63	8.93	4.21	4.86	4.82	6.37
LSD	0.1665	0.1447	0.2704	0.1887	0.1577	0.2147

Letters within columns indicate least significant differences (LSD), at **p = 0.01, *p = 0.05, ns: Non significant

Water uptake: Throughout the storage period, a marked reduction in water uptake by the flowering stalk was found in both the control group flowers and the flowers treated with 1-MCP. The results from Table 2 summarizes the water uptake trends in patumma flowers from day 2 to day 12 of storage. Highly significant differences in the water uptake during storage were observed. The most effective application of 1-MCP in promoting the distilled water uptake was found to be 100 ppb for 12 h.

Vase life: The results from Table 3 show that different 1-MCP fumigation periods have significant effect on vase life. Pretreatment flowers with 100 ppb 1-MCP for 12 h extended the longest vase life by 10.25 days, compared to the controls.

Total anthocyanin content: The results presented in Table 4 show that anthocyanin content in the bract tended to decline continually during storage. The significant difference in anthocyanin content, between treated flower and control, was presented during storage. Flower-treated with 300 ppb of 1-MCP for 15 h maintained the highest anthocyanin content (13.64 mg/100 g fresh weight) by the 8 DAV. Afterwards, all treatments showed no significant difference of anthocyanin content since 10 DAV.

Bract colour: The results indicated that flowers treated with 100 ppb of 1-MCP for 15 h retained the bract colour in terms of the highest L* and a* values throughout the storage. These indicated that flowers treated with 100 ppb 1-MCP for 15 h retained the highest brightness colour and

Table 3: Vase life of patumma after fumigation with 1-MCP

Factors	Vase life (days)
Conc. (ppb)	
0	8.95
100	8.64
300	8.38
F-test	ns
CV (%)	4.81
LSD	0.4046
Time (h)	
12	9.24a
15	8.07b
F-test	*
CV (%)	4.25
Conc.×Time	
0 ppb 12 h	8.10b
0 ppb 15 h	7.65b
100 ppb 12 h	10.25a
100 ppb 15 h	8.45b
300 ppb 12 h	8.65b
300 ppb 15 h	8.83ab
F-test	*
CV (%)	4.09
LSD	0.5623

Letters within columns indicate least significant differences (LSD), at *p = 0.05, ns: Non significant

Table 4: Anthocyanin content of patumma after fumigating with 1-MCP

	Anthocyanin content (mg/100 g FW) at DAV					
Factors	2	4	6	8	10	12
Conc. (ppb)						
0	20.36	20.22	13.05	12.33b	12.26	14.60a
100	20.92	20.17	13.42	12.39b	13.04	12.81b
300	20.72	20.29	13.40	13.22a	12.69	14.27a
F-test	ns	ns	ns	*	ns	**
CV (%)	4.29	7.76	3.82	2.97	3.03	2.92
LSD	0.2289	0.1396	0.1607	0.2149	0.2923	0.3645
Time (h)						
12	23.05a	20.05b	13.44	12.65	12.55	13.90
15	22.28b	20.39a	13.15	12.64	12.78	13.89
F-test	**	*	ns	ns	ns	ns
CV (%)	2.56	5.58	3.78	7.55	3.48	3.64
Conc.×Time						
0 ppb 12 h	20.50c	20.15	13.37ab	12.49b	11.80	14.74
0 ppb 15 h	20.21c	20.28	12.74c	12.16b	12.72	14.46
100 ppb 12 h	23.22ab	19.95	13.72a	12.65b	13.44	12.97
100 ppb 15 h	20.62bc	20.39	13.13bc	12.13b	12.64	12.66
300 ppb 12 h	23.42a	20.07	13.22abc	12.80b	12.41	14.01
300 ppb 15 h	20.02c	20.51	13.58ab	13.64a	12.97	14.54
F-test	**	ns	*	*	ns	ns
CV (%)	7.65	6.59	1.53	2.08	2.02	4.90
LSD	0.2350	0.1846	0.1897	0.2788	0.3862	0.5597

Letters within columns indicate least significant differences (LSD), at **p = 0.01, *p = 0.05, ns: Non significant

Table 5: Colour of patumma bract in term of L* value during vase life

	L* at DAV					
Factors	2	4	6	8	10	12
Conc. (ppb)						
0	45.57b	46.44b	49.23	44.31b	49.05a	47.79b
100	47.75a	50.17a	48.05	48.13a	42.65b	51.09a
300	49.48a	46.33b	47.75	47.66a	38.19c	42.73c
F-test	**	**	ns	**	**	**
CV (%)	3.37	4.00	2.67	5.05	9.04	2.44
LSD	0.7114	0.7459	0.6848	0.7855	0.9316	0.9498
Time (h)						
12	46.43b	47.50	49.12a	46.33	45.08a	48.88a
15	48.76a	47.79	47.56b	47.07	41.62b	45.08b
F-test	**	ns	*	ns	**	**
CV (%)	3.54	4.47	2.61	5.43	2.24	3.59
Conc.×Time						
0 ppb 12 h	43.44c	45.94c	50.77	45.43bcd	50.41a	49.73a
0 ppb 15 h	47.70ab	46.95bc	47.69	43.18d	47.69a	44.44b
100 ppb 12 h	46.01bc	49.36ab	47.83	45.19cd	47.83a	50.77a
100 ppb 15 h	49.49a	50.97a	48.27	51.06a	37.47b	51.50a
300 ppb 12 h	49.85a	47.20bc	48.78	48.35ab	36.99b	45.24b
300 ppb 15 h	49.10a	45.45c	46.72	46.96bc	39.51b	40.37c
F-test	**	**	ns	**	**	**
CV (%)	3.01	4.00	2.55	4.60	7.65	1.73
LSD	0.9795	1.0548	0.9592	1.0776	1.2217	1.2829

Letters within columns indicate least significant differences (LSD), at **p = 0.01, *p = 0.05, ns: Non significant

redness (L* value 51.50, a* value 15.12) at the end of vase life by 12 DAV (Table 5, 6). For b* values, the results from Table 7 indicate that 1-MCP fumigation affected patumma bract's colour in terms of the b* value only on the 4th DAV.

The effects of different concentrations (0, 100 and 300 ppb) in combination with two fumigation periods (12 and 15 h) of 1-MCP on the vase life and other postharvest characteristics of patumma flower cv. Chiang Mai Pink was investigated.

For weight loss of the flowers, the results revealed that during storage, the weight of the patumma flower steadily declined. In general, loss of flowering weight is one of the most important causes responsible for flower quality deterioration. Flowers treated with 1-MCP started to show a significantly lower percentage of flowering weight loss than that of the control flowers from 2 DAS to 10 DAS. Throughout the vase life time, the least flowering weight loss received from treating with 1-MCP at 300 ppb for 15 h was observed. This observation is consistent with the findings of Wu *et al.* (2009) whom reported that the treatment with 0.5 μL L^{-1} 1-MCP significantly delayed weight loss of Chinese chive scape flowers. The opposite result was confirmed by Chutichudet *et al.* (2010b), who found that 1-MCP had no effect on weight loss in Siam tulip flowers. This was probably due to the fact that the patumma flower has fresh reproductive organs which are cut at a young stage and considered as a perishable product and susceptible to readily loosing a lot of water through transpiration immediately after cutting (Nakano *et al.*, 2003; Bunya-Atichart *et al.*, 2004). The reduction in weight loss of flowering stalk during storage life in 1-MCP-treated flowers may be due to 1-MCP interfering with the autocatalytic production of ethylene (Sisler *et al.*, 1996), which in these cases may be depended upon the concentration applied as 1-MCP and fumigation

Table 6: Colour of patumma bract in term of a* value during vase life

	a* at DAV					
Factors	2	4	6	8	10	12
Conc. (ppb)						
0	12.38	12.30	13.77a	11.73b	12.96a	13.52
100	12.71	11.78	12.90b	13.05a	11.58ab	13.59
300	11.92	12.47	13.33ab	12.61ab	10.25b	11.59
F-test	ns	ns	*	*	**	ns
CV (%)	2.64	2.11	1.22	2.49	1.88	3.78
LSD	0.4087	0.3693	0.2418	0.3552	0.5430	0.6468
Time (h)						
12	12.56	12.13	13.64a	12.13	11.45	13.06
15	12.11	12.23	13.03b	12.80	11.75	12.84
F-test	ns	ns	*	ns	ns	ns
CV (%)	2.64	2.16	1.24	2.68	2.86	3.42
Conc.×Time						
0 ppb 12 h	12.11	12.06	14.12a	11.73	12.93a	13.87ab
0 ppb 15 h	12.64	12.53	13.42ab	11.73	13.00a	12.93abc
100 ppb 12 h	13.36	11.33	13.30ab	12.61	12.05a	12.38bc
100 ppb 15 h	12.05	12.22	12.50b	13.49	11.12ab	15.12a
300 ppb 12 h	12.20	13.00	13.48a	12.05	9.37b	12.39bc
300 ppb 15 h	11.63	11.94	13.18ab	13.17	11.13ab	10.84c
F-test	ns	ns	*	ns	**	*
CV (%)	2.61	2.06	1.14	2.44	1.84	3.38
LSD	0.5774	0.5212	0.3403	0.5013	0.7673	0.9131

Letters within columns indicate least significant differences (LSD), at **p = 0.01, *p = 0.05, ns: Non significant

time in order to bind the ethylene receptors. Thus, the decrease of flowering weight from treating with 1-MCP at 300 ppb for 15 h were observed during vase life (Lalel *et al*., 2003). However, mechanisms of 1-MCP for slowing the flowering loss in cut patumma have not been determined.

The results on water uptake by the flowering stalk showed a significantly different trend during vase life. This is due to the fact that after cutting at a young stage, patumma flowers have no renewable source of water to compensate for that lost through transpiration. Detached flowers therefore experience water stress, which might be involved in activating senescence (Apelbaum and Yang, 1981). In this study, flowers fumigated with 100 ppb of 1-MCP for 12 h continued to absorb the maximal distilled water since 6 DAV through 12 DAV. These data are consistent with those of Chutichudet *et al*. (2010b) indicated that the water uptake by flowering stalk of Siam Tulip showed that treatment with 1-MCP at 300 ppb for 8 h and 1-MCP at 600 ppb for 4 h remarkably increased water uptake through flowering stem more than in the control flowers. This indicated that a positive water balance in these flowering stems could be improved by 1-MCP application after cutting (Blankenship and Dole, 2003). In addition, these results are in line with the results of Celikel and Reid (2002) who found that 1-MCP could prevent the rapid wilting of carnation Sandra, alstroemeria (Alstroemeria), snapdragon, larkspur (*Consolida ambigua*), sweet william (*Dianthus barbatus*), stock (*Matthiola incana*) and penstemon Firebird (Serek *et al*., 1995a). While, Chutichudet *et al*. (2010a) found that 1-MCP fumigating had no effect on the water uptake of Patumma flowering stalk during vase life.

Table 7: Colour of patumma bract in term of b* value during vase life

	b* at DAV					
Factors	2	4	6	8	10	12
Conc. (ppb)						
0	-4.38a	-3.63a	-6.24	-3.43a	-2.26	-3.22
100	-5.87b	-5.90b	-5.40	-5.06b	-1.66	-3.52
300	-4.79ab	-4.79ab	-5.94	-4.25ab	-0.53	-1.63
F-test	*	**	ns	*	ns	ns
CV (%)	5.29	4.83	2.28	6.75	3.14	1.87
LSD	0.4232	0.4524	0.3424	0.4590	0.6447	0.7614
Time (h)						
12	-4.34a	-4.09a	-5.97	-4.18	-1.25	-2.37
15	-5.68b	-5.46b	-5.75	-4.31	-1.72	-3.42
F-test	**	*	ns	ns	ns	ns
CV (%)	5.00	5.65	5.48	7.81	3.00	1.53
Conc. ×Time						
0 ppb 12 h	-3.26a	-2.32a	-6.12	-3.46	-2.56	-2.96
0 ppb 15 h	-5.49bc	-4.94bc	-6.36	-3.40	-1.97	-3.66
100 ppb 12 h	-5.83c	-6.10c	-5.86	-4.73	-1.35	-2.09
100 ppb 15 h	-5.92c	-5.70c	-4.94	-5.38	-1.97	-5.33
300 ppb 12 h	-3.93ab	-3.85ab	-5.93	-4.35	-0.16	-1.67
300 ppb 15 h	-5.64c	-5.73c	-5.95	-4.14	-1.23	-1.60
F-test	**	**	ns	ns	ns	ns
CV (%)	3.99	3.00	2.40	7.26	3.29	1.95
LSD	0.5881	0.6261	0.4854	0.6525	0.9144	1.0830

Letters within columns indicate least significant differences (LSD), at **p = 0.01, *p = 0.05, ns: Non significant

For shelf life, flower longevity of patumma in this study showed a significant difference between treatments. 1-MCP at 100 ppb for 12 h notably had the longest vase life of 10.25 days. Generally, during storage, water uptake by flowering stalk was related to the shelf life. Relatively more water uptake by the flowering stems is often associated with extending the vase life of cut flower (He *et al*., 2006). These results suggest that there may be a longer vase life for flowers treated with 1-MCP at 100 ppb for 12 h because this treatment induced the flower to absorb the most water. This implies that 1-MCP, for full effectiveness, should be applied at a low concentration for a longer period (Serek and Sisler, 2001). This result is consistent with the findings of Valentines *et al*. (2005) who showed that a pre-treatment with 1-MCP at 1 nll^{-1} for 12 h was sufficient to extend the vase life of Lollypop flowers by 4 days. However, the effect of 1-MCP remains quite variable among the reported studies. Chutichudet *et al*. (2010a), for example, reported that after pre-treatment with a range of 1-MCP dosages (0, 300, 600 and 900 ppb) in two fumigation periods (4 and 8 h) no beneficial effect to the vase life of patumma flower was noted. A possible explanation for these effects of 1-MCP may be that the effective durations for 1-MCP application should be 12-24 h to achieve a full response (Blankenship and Dole, 2003). Sisler *et al*. (1996) demonstrated that 1-MCP completely protects senescence of carnations when given a 24 h exposure at 0.5 nll^{-1}. These results could be explained by the fact that active concentrations of 1-MCP vary widely, as do fumigation periods (Fan *et al*., 1999). Thus, additional experiments, which apply 1-MCP for longer periods, are needed to confirm the effects of 1-MCP related to extending the vase life and other postharvest physiological characteristics of the patumma flower.

The results on anthocyanin content of patumma flower were relatively affected by treatment with 1-MCP during vase life, from 2 DAV to 8 DAV. Flowers fumigated with 1-MCP at 300 ppb for 15 h had an extreme anthocyanin content of 13.64 mg/100 g FW) at 8 DAV. The effect of 1-MCP on anthocyanin content has been consistent with the results of Chutichudet *et al.* (2010a) whom revealed a pretreatment of patumma flowers with 1-MCP at 600 ppb for 4 h and 900 ppb for 8 h was effective in controlling anthocyanin degradation, a similar response that has been previously documented by Chutichudet *et al.* (2010b). They found that Siam Tulip flowers treated with 1-MCP at 300 ppb for 8 h benefited by retaining the maximal anthocyanin content of 32.95 mL per 100 g FW on 12 DAS. From this study, the results indicated that the application of 1-MCP, especially at concentration of 300 ppb for 15 h, clearly influenced anthocyanin degradation in patumma's bract. Generally, anthocyanin pigment is often degraded after harvest (Underhill and Critchley, 1994) due to the deterioration in membrane function of bract (Jiang and Chen, 1995; Jiang *et al.*, 2004). These results suggest that 1-MCP plays a significant role in controlling the senescence of the patumma flower. Therefore, commercial use of 1-MCP may enhance patumma quality under postharvest conditions. A possible explanation for the effects of 1-MCP being beneficial for maintaining the anthocyanin stability may be that pretreatment with 1-MCP could reduce damage to the membrane in fresh product, which is an important factor involved in retaining the pink colour of the bract in the patumma flower (Hershkovitz *et al.*, 2005). Unfortunately, the activity of degrading enzymes and other biochemical and physiological parameters were not analyzed during storage. However, the possibility that the mechanism by which 1-MCP exerts its activity may be through the direct inhibition of anthocyanin degradation is unclear at present. Furthermore, with respect to detailed knowledge available on anthocyanin degradation, very little is known about its stability and catabolism in patumma flower. Further investigation on the effect of 1-MCP related to this characteristics is warranted.

For bract colour, a significant change of colour in terms of L* and a* values were observed during storage. The changes in L* value tended to decline with further storage resulting in the bract colour becoming darker. The reduction in a* values resulted in the patumma's bract changing to a lower intensity of red. The application of 1-MCP at 100 ppb for 15 h significantly maintained the bract colours both in terms of L* and a* values compared to untreated control flowers, except b* value at 12 DAV. Bract of flower fumigated with 1-MCP at 100 ppb for 15 h preserved the best colour retention in terms of brightness and redness of bract. This may be due to the response of patumma flower to exposure times to 1-MCP at different concentrations (Serek *et al.*, 1995b). This behavior seems to be a general effect of 1-MCP in most of the studied flowers, such as patumma (Chutichudet *et al.*, 2010a) and the Siam tulip (Chutichudet *et al.*, 2010b). Both studies cited a positive effect of 1-MCP treatments on preserving the flower colour. Therefore, patumma flower exposed to 100 ppb of 1-MCP showed a potential trend to preserve better bract colour during vase life. However, the cause of this 1-MCP effectiveness in colour retention has been limited. In addition, the specific mechanism of 1-MCP in maintaining the colour of patumma bract is still scarcely known. To understand 1-MCP efficacy for maintaining the bract colour, analysis of the enzyme level of pigment degradation will be required.

In conclusion, it was found that the efficacy of 1-MCP application for extending the vase life and maintaining patumma quality is influenced by concentration dose and treatment duration. Patumma flower treated with 1-MCP at 300 ppb for 15 h exhibited the least weight loss and the best retention of anthocyanin content. While, flowers treated with 1-MCP at 100 ppb for 12 h activated the highest water uptake and the longest flower longevity. Treatment with 100 ppb

1-MCP for 15 h showed the best colour retention of flowering bract in terms of L* and a* values. Thus, 1-MCP treatment may be a promising technique for extending the vase life and maintaining postharvest quality of the patumma flower during storage.

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