THE EFFECTS OF STORAGE DURATION AND TEMPERATURE ON THE QUALITY OF FOLIAGE POTTED PLANTS DURING SIMULATED TRANSPORTATION

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ABSTRACT

In this study, five types of foliage potted plants (Alocasia reginula, Leudeboria socialis, Leudeoboria petiolata, Tradescantia spathacea and Peperomia puteolata) were stored under different temperature during simulated transportation. The commercial-stage plants of each selected varieties were kept in the dark at 5, 10, 15 and 20 °C without watering. After 3-4 days interval, the potted plants were removed and placed at retail temperature (25 ± 2 °C). The quality of the potted plants was assessed in term of quality scoring, SPAD value and colour (lightness, chroma and hue). The results in this study suggested that all plants are not suitable to store at 5 °C as they exhibited chilling symptoms after removal. Storage temperatures of 15 - 20 °C in the dark is recommended for all foliage potted plants up to 10 days without watering in this study. Overall, potted plants should be stored and shipped for a brief duration at optimum conditions with minimal quality deterioration.

Keywords: dark storage, chilling injury, chlorophyll, leaf wilting, ornamental

INTRODUCTION

Loss of quality of foliage potted plants is a major problem in the ornamental distribution chain due to leaf wilting and defoliation, resulting in significant losses (Reid and Jiang, 2012). During transportation, potted plants can be adversely affected by high temperatures, exposure to ethylene, or darkness, promoting petal abscission and leaf yellowing which lead to considerable product losses (Ferrante et al., 2015). According to Toscano et al. (2018), the critical stages in post-production of ornamental plants usually occurred during transportation and storage in the warehouse and during the recovery stage in retailer's shops and end-user. The lack of specific care of ornamental potted plants during transport and storage and the quality is often compromised. The commercial value and quality of flowering and foliage plants could be adversely affected by high temperature, exposure to ethylene, prolonged dark storage leading to petal abscission and leaf yellowing thus increasing product losses in the market.

Temperature management is one of the best methods to control product quality in the distribution chain of ornamental potted plants. The optimum temperature and the optimum length of storage and transportation duration of potted plants need to be determined by considering the tolerance threshold of the species. Plants transported by sea shipment is considered the most economical method compared to air shipment but required a longer time. Long-term transportation issues related with long term storage namely leaf and flowering discolouration and abscission, failure of buds to open, terminal growth, and disease infection (Rudnicki et al., 1991). Furthermore, there is a scarcity of knowledge about foliage potted plants, which mostly pertains to 1980s research (Ferrante et al., 2015). Because the health of the leaves (foliage greenness) are often linked to the plant's commercial value, it is vital to gain new information on the storage and transportation of foliage potted plants to avoid losses during the distribution chain. The main objective of this study was to investigate the effect of different temperature to improve the display life of five ornamental foliage potted plants during simulated transportation.

MATERIALS AND METHODS

Plant materials

Five types of ornamental potted plants *Alocasia reginula, Leudeboria socialis, Leudeoboria petiolata, Tradescantia spathacea* and *Peperomia puteolata* were used in this study. The plants were conditioned with proper agronomy practices and grown to reach commercial-stage with 6-9 leaves per plant and watered a day before transporting to Postharvest Complex, MARDI Serdang, Selangor within one hour. The selection of good quality ornamental potted plants were packed in corrugated boxes and then kept in the dark at 5, 10, 15 and 20 °C (relative humidity: 85-90%) without water for two weeks. The aim of different temperatures and storage time was to investigate the effect of transportation on plant quality at both optimal and suboptimal temperatures. Immediately after storage, the plants were watered and placed at room temperature (25 ± 2 °C) to simulate a display period for 3 to 4 days in the retail market. For each combination of storage time and temperature, four plants were stored.

Quality scoring of foliage potted plants

The quality of the potted plants was scored both immediately after storage (so just before the display period), and after a display period of 3 days according to Tromp et al. (2015) with some modifications (Table 1). Foliage plants were scored based on the quality of the leaves (yellowing, fungal infection, abscised, chilling injury (dark spot on leaves)).

Table 1: Quality of foliage potted ornamental plants

Quality score	Description
9	Very good; less than 10 % defects on foliage
8	Good;less than 20% defectson foliage
7	Fairly ok; minor less than 30 % defects on foliage
6	Sufficient; less than 40% defects on foliage
5	Insufficient; more than 40% defects on foliage- and/or abscised leaves
≤ 4	Bad and unmarketable; serious defects on foliage

Leaf colour measurement

Average leaf colour (three leaves per plant) was measured by using a portable chromameter (model CR-400 Minolta Corp., Osaka, Japan). The $L*$ value ranged from 0 = black to 100 = white. Chroma ($C*$) is the intensity or purity of the hue. The $h°$ is an angle in a colour wheel of 360°, with 0° or 360° representing red hue, whilst angles of 90°, 180° and 270° represent yellow, green and blue hues, respectively. The results were presented as lightness ($L*$), colour intensity ($C*$) and colour appearance parameter, hue ($h°$). The light projection aperture was positioned directly on top center of the leaves and three readings from three separate leaves per plant were taken.

SPAD value measurement

Three mature leaves were selected from each plant and three SPAD readings were then taken from the center of each of three leaves using a SPAD-502 meter (Konica-Minolta, Japan). Three measurements per leaf were averaged to provide a single leaf observation value to indicate foliage greenness or the relative chlorophyll content of leaves according to Wang et al. (2005) with slight modification.

Statistical analysis

The experiment was a completely randomized design with three replicates of three plants. The data were subjected to Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) procedure at $P<0.05$ to test the differences between treatment means (SAS ver. 9.4).

RESULTS AND DISCUSSION

Alocasia reginula, Leudeboria socialis, Leudeoboria petiolata, Tradescantia spathacea and *Peperomia puteolata* are valued for its decorative foliage as indoor plants. *A. reginula* (Figure 1a) is known for its velvety, dark and broad leaf. *L. socialis* (Figure 1b) has stalkless, broadly lance-shaped succulent type of green leaves with black spots whereas *L. petiolata* (Figure 1c) is a small hardy bulb with dark spots on glossy, dark green, heart-shaped leaves. *T. spathacea* (Figure 1d) have leaves that are green on the upper side and vividly purple underneath. *P. puteolata* (Figure 1e) is a semi-succulent plant with small whorled ovate leaves patterned in dark green and white venation and are commonly grown as decorative plants in hanging baskets. Since they are grouped under sub and tropical plants, they tend to be more tolerant of lower light with minimal care and watering. These plants vary in size, form, and leaf shape. Due to these variations, these plants interacted differently when placed under different storage temperatures and duration in the dark without water.

In Table 2, all plants were evaluated with an average score of 5.33 indicating the plants have foliage defects and/or abscised leaves when kept at the lowest temperature (5 °C). Most of the plants started to exhibit signs of chilling injury after 6 days of cold storage such as leaf defoliation (*P. puteolata*) and the appearance of dark water-soaked areas on leaves (*L. petiolata* and *P. puteolata* plants). Plants such as *A. reginula* and *T. spathacea* were able to tolerate 10 – 20 °C with a score ranging from 6 – 8 (Table 2a and 2d). Plants of *L. socialis, L. petiolata* and *P. puteolata* are most suited to be transported at 15 – 20 °C with a score ranging from 6 -7 (Table 2b, 2c and 2e, respectively). When stored under a prolonged period, *L. socialis, L. petiolata* and *P. puteolata* were able to withstand 6 days and 9 days for plants of *A. reginula* and *T. spathacea* in the dark without water. After the recommendation period, most of the plants began to exhibit leaf senescence (wilting and abscission) due to drought stress with a score of 5 and below (Table 2). Quality losses in potted plants due to wilting is a typical problem in the ornamental distribution chain as plants begin to lose water by evapotranspiration (Reid and Jiang, 2012). Drought stress and water deficit would increased leaf senescence when the amount of water in the growth media is inadequate to replace the water lost via transpiration (Luca et al., 2021). Hence, it is vital to provide sufficient water in foliage potted plants to avoid drying of growing media during the distribution chain since it would eventually affect the foliage quality and pricing.

In this experiment, *A. reginula* (Table 2a) and *L. socialis* (Table 2b) recorded the highest SPAD value at 5 and 10 °C. Plants of *L. petiolata, T. spathacea* and *P. puteolata* showed constant SPAD value ($p>0.05$) at all temperatures (Table 2c, 2d and 2e, respectively). Compared to other plants, the leaves of *A. reginula* and *L. socialis* were thicker. The loss of chlorophyll in the leaves was significantly lower for plants kept at 5 and 10 °C but chilling injury symptoms were more apparent after a display period of 3 days at ambient temperature for both plants. In term of storage duration, SPAD value of *A. reginula* (Table 2a) and *L. petiolata* (Table 2c) decreased significantly ($p<0.05$) with storage time whereas plants of *T. spathaceae* have a significantly lower SPAD value at the end of storage (Table 2d). The decrease of SPAD value in these three plants suggested the onset of plant senescence with the decreasing chlorophyll content in the leaves. No significant changes in SPAD value were recorded for *L. socialis* (Table 2b) and *P. puteolata* (Table 2e) during storage. The onset of senescence of *P. puteolata* is mostly due to leaf defoliation and not yellowing during storage. For *L. socialis* plants, the leaves tend to rot due to their succulent characteristics. However, the readings might not be taken accurately since SPAD readings were also influenced by the specific part of the foliage and uneven distribution of the chlorophyll within the leaf (Yuan et al., 2016). Besides that, SPAD readings may also be affected by specific leaf area and thickness as reported by Yamamoto et al. (2003) in sorghum and pigeon pea and other factors such as cultivar, year, growth stage and leaf position in rice plants (AtaUl-Karim et al., 2014; Hu et al., 2014).

The leaf colour (L^*, C^* and $h°$) of *A. reginula* (Table 2a) and *P. puteolata* (Table 2e) recorded no changes ($P > 0.05$) at all temperatures since the colour of the plants were well maintained in the dark during prolonged storage. The only negative quality change observed for these plants were due to chilling injury (severe leaf defoliation). At sub-optimal temperature, plants of *L. socialis* and *L. petiolata* tend to have darker green foliage as indicate by significantly ($p<0.05$) lower L^* and C^* values, and higher $h°$ value (Table 2b and 2c) due to chilling stress. However, when the temperature increased to optimal storage temperature (15 and 20 °C), the L^* and C^* values increased along with a decrease in $h°$ value indicating the leaves were lighter and less intense in term of colour appearance. This might also indicate the onset of plant senescence when green foliage appeared to be more prone to yellowing or wilting. Plants of *T. spathaceae* also showed a similar trend in term of C* and h° value except for L^* value (Table 2d). The leaf colour of *T. spathaceae* showed constant L^* ($p>0.05$) indicating there are no changes in lightness in all storage temperatures. The L^* *and* C^* increased significantly with storage duration ($P<0.05$) indicating a lighter colour of *A. reginula, L. sosialis* and *T. spathaceae* . The $h°$ value of *A. reginula* remained unchanged ($P<0.05$) due to its dark velvety leaf whereas there was a significant drop ($P<0.05$) in both *L. sosialis* and *T. spathaceae* plants indicating as an indication of degreening associated with degradation of chlorophyll content (Toivonen and Brummell, 2008). However, at the end of the storage, visual observation of the leaves was found to be more brown than yellow due to wilting.

During prolonged storage, some of the plants exhibit leaf wilting due to drought stress and lack of light even at optimal temperature (15 – 20 °C). Due to a lack of light during transportation, foliage potted plants were forced to expend their energy reserves by respiring, which caused leaf senescence initiation, which resulted in leaf abscission (Ferrante and Reid, 2006; Tromp et al., 2015). Besides that, the presence of ethylene in the storage environment might also cause the leaf to abscise even at extremely low concentrations e.g. 0.1 ppm (Macnish et al., 2011). Low-temperature storage is an important factor enabling the preservation of freshly cut flowers without a great loss of their quality but it may be detrimental to potted plants originated in subtropical or tropical regions. Optimum shipping temperature for potted plants in these regions usually falls in the range of 15 - 18 °C to avoid chilling injury (Rudnicki et al., 1991) and high relative humidity to avoid excessive desiccation (Tromp et al., 2015).

CONCLUSION

To conclude, the quality deterioration of foliage potted plants relied on the storage temperature and storage duration. Storage temperatures of 15 - 20 °C in the dark is recommended for all foliage potted plants up to 10 days without watering in this study. Overall, foliage potted plants should be stored and shipped for a brief duration at optimum conditions with minimal quality deterioration.

Figure 1: Types of foliage potted plants a) Alocasia reginula b) Leudeboria socialis c) Leudeoboria petiolate d) Tradescantia spathacea e) Peperomia puteolata

Table 2 : Effects of different temperature on the leaf colour, SPAD content and quality scoring of a) *Alocasia reginula,* b) *Leudeboria socialis,* c) *Leudeoboria petiolata,* d) *Tradescantia spathacea and* e)*Peperomia puteolata during storage*

a. Alocasia reginula	**Quality score**	**SPAD value**	**Colour**		
			L*	***C****	***h°***
Storage temperature					
5°C	5.15c	69.02a	28.78a	2.41a	150.10a
10°C	6.55b	61.66b	28.80a	2.39a	149.90a
15°C	6.80a	58.90c	27.91a	2.25a	148.82a
20°C	6.90a	55.24c	28.15a	2.11a	149.35a
F-significant	**	**	ns	ns	ns
Storage duration					
D0	8.31a	69.73a	27.55c	2.57b	147.21a
D3	7.66b	62.18b	29.88b	2.68b	145.19a
D6	6.50c	59.60bc	28.90b	2.86b	144.31a
D9	5.19d	55.83cd	29.11b	3.17a	143.92a
D12	4.09e	53.32d	33.80a	3.38a	145.81a
F-significant	**	**	**	**	ns

b. Leudeboria socialis	**Quality score**	**SPAD value**	**Colour**		
			L*	***C****	***h°***
Storage temperature					
5°C	5.37c	51.01a	33.68c	17.82c	128.57a
10°C	5.45c	49.77a	35.61b	18.74b	126.28b
15°C	6.50b	44.49b	37.83b	20.10b	126.11b
20°C	7.00a	43.78b	39.41a	22.37a	123.74c
F-significant	**	**	**	**	**
Storage duration					
D0	9.00a	53.11a	33.89b	16.25c	128.77a
D3	9.00a	52.36a	34.77b	16.09c	129.46a
D6	6.60b	53.04a	34.74b	15.97c	129.83a
D9	5.60c	51.90a	32.44b	19.64b	128.09a
D12	4.00d	37.82b	43.41a	27.46a	119.55b
F-significant	**	**	**	**	**

c. *Leudeboria petiolata*	Quality score	SPAD value	Colour		
			*L**	*C**	*h°*
Storage temperature					
5°C	5.37b	44.56a	38.79b	20.91b	126.86a
10°C	5.75b	43.23a	40.91a	22.26a	126.05b
15°C	6.50a	42.54a	40.64a	21.89a	126.56ab
20°C	6.48a	42.03a	40.40a	22.20a	126.32b
F-significant	**	ns	**	**	*
Storage duration					
D0	9.00a	45.20a	39.31a	22.19a	126.00a
D3	9.00a	44.15a	39.43a	22.36a	126.16a
D6	6.60b	41.62b	40.31a	22.21a	126.41a
D9	5.55c	41.25b	40.33a	21.52a.	126.42a
D12	3.95d	42.10b	41.33a	22.15a	126.64a
F-significant	**	**	ns	ns	ns

d. *Tradescantia spathacea*	Quality score	SPAD value	Colour		
			*L**	*C**	*h°*
Storage temperature					
5°C	5.50b	40.49a	34.90a	17.10b	125.35a
10°C	7.00a	38.94a	36.19a	19.56a	124.33ab
15°C	7.00a	37.96a	35.34a	19.79a	123.76bc
20°C	8.00a	38.95a	35.98a	20.11a	124.56c
F-significant	**	ns	ns	**	**
Storage duration					
D0	9.00a	41.23a	37.58a	17.64c	123.11a
D3	9.00a	42.34a	37.55a	17.44c	123.24a
D6	7.75b	41.23a	36.04b	16.05c	125.23a
D9	6.20c	39.15a	33.66c	20.65b	124.33a
D12	5.35d	33.13b	32.72c	23.57a	122.00b
F-significant	**	**	**	**	**

e. *Peperiomia puteolata*	Quality score	SPAD value	Colour		
			*L**	*C**	*h°*
Storage temperature					
5°C	5.25b	43.88a	38.83a	27.11a	125.03a
10°C	7.00a	41.63a	37.43a	24.96a	125.78a
15°C	7.00a	39.94a	39.19a	26.56a	125.09a
20°C	7.13a	43.75a	39.10a	26.57a	125.80a
F-significant	**	ns	ns	ns	ns
Storage duration					
D0	9.00a	43.25a	39.04a	27.13a	124.55a
D3	9.00a	43.11a	37.51a	26.64a	125.02a
D6	7.75b	41.47a	39.70a	26.68a	125.95a
D9	5.90c	40.57a	38.06a	25.84a	125.60a

D12	5.15d	42.55a	38.86a	25.22a	126.00a
F-significant	**	ns	ns	ns	ns

Mean values in the same column followed by different letters indicate significant differences (P < 0.05) using Duncan Multiple Range Test.

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