Non-decorative Floral Organs Largely Contribute to Transpiration and Vase Life of Cut Hydrangea Flowers with Lacecap Inflorescence

Yoshikuni Kitamura1*, Tatsuya Uemachi2 and Yukari Kato1

1Faculty of Agriculture, Shinshu University, Minamiminowa, Nagano 399-4598, Japan
2School of Environmental Science, The University of Shiga Prefecture, Hikone 522-8533, Japan

We compared transpirations and vase lives of cut hydrangea (Hydrangea spp.) flowers using two cultivars with lacecap inflorescence (‘Blue sky’ and ‘S-1’) and their mutants with hortensia inflorescence (‘BM-1’ and ‘SM-1’). There was no significant difference in the transpirations from cut flowers with the lacecap and hortensia inflorescences in the two cultivars. However, transpiration from ‘S-1’ cut flowers tended to exhibit higher transpiration than ‘SM-1’. There was also no significant difference in the vase lives of ‘Blue sky’ and ‘BM-1’. However, ‘S-1’ had a significantly shorter vase life (3 days) than its mutant ‘SM-1’. This was due to the greater number of total florets in ‘S-1’ cut flowers than ‘SM-1’. The non-decorative floret clusters and clusters of petals, stamens, and pistil of decorative florets exhibited lower temperatures than decorative sepals in both ‘Blue sky’ and ‘BM-1’ on thermal images. Therefore, we estimated the transpiration from the non-decorative florets and studied the effect of removal of non-decorative florets on the vase life of cut flowers using two lacecap cultivars, ‘Blue sky’ and ‘Fairy eye’. Estimated transpirations from the non-decorative florets of ‘Blue sky’ and ‘Fairy eye’ accounted for approximately 61.8% and 39.7%, respectively, of total transpirations per cut flower, and the removal of non-decorative florets significantly extended the vase lives of cut flowers (18 and 22 days, respectively). The difference in the contribution of the non-decorative florets to the transpiration between the cultivars is due to the difference in the number of non-decorative florets in the inflorescences. We conclude that the use of cut flowers that do not bear too many non-decorative florets and/or treatments that suppress the transpiration from non-decorative florets would be effective in extending the vase life of cut hydrangea flowers with lacecap inflorescence.

Key Words: decorative floret, double-flowered cultivar, Hydrangea spp., inflorescence type, thermal imaging.

Introduction

Hydrangeas (Hydrangea spp.) are popular ornamental plants that are cultivated in many countries. In recent years, the demand for cut hydrangea flowers has been increasing in Japan and cut hydrangea flowers at two different harvest stages, fresh- and antique-stage, are marketed (Kitamura, 2013). Hydrangea inflorescences consist of non-decorative florets, which bear tiny sepals, and decorative florets, which bear large decorative sepals. The inflorescences of hydrangeas are classified as hortensia and lacecap, according to the arrangement of the two types of florets (Uemachi and Nishio, 2005; Uemachi et al., 2006).

Today, nearly all hydrangea cultivars in the cut flower market have hortensia inflorescences. Lacecap inflorescences have a much larger number of non-decorative florets than hortensia inflorescences, and petals and stamens drop from them soil around the cut flower. However, this issue is restricted to single-flowered cultivars because the non-decorative florets of double-flowered cultivars with lacecap inflorescences have few petals and stamens (Uemachi et al., 2012). Thus, there is also a demand for these double-flowered cultivars, which have ornamental value as cut flowers (Fig. 1A).

Defoliation, reduction of the decorative florets, and covering of the inflorescence are effective to extend the vase life of cut hydrangea flowers with hortensia inflorescences, and it has been suggested that these treatments extend the vase life by suppressing transpiration from the cut flowers (Kitamura and Ueno, 2015; Mega, 1957). The vase life of cut hydrangea flowers with lacecap inflorescences is currently unstudied. However, since lacecap inflorescences have fewer decorative...
florets than hortensia inflorescences (Fig. 1), they may have lower transpiration and thus a longer vase life.

In this study, we compared the transpirations and vase lives of cut hydrangea flowers with lacecap and hortensia inflorescences using two lacecap cultivars and their inflorescence mutants with hortensia inflorescences, as a model. We also investigated the factors that regulate the transpirations and vase lives of cut flowers with lacecap inflorescence.

Materials and Methods

Plant materials

Five hydrangea cultivars, ‘Blue sky’, ‘BM-1’, ‘S-1’, ‘SM-1’, and ‘Fairy eye’ were used (Fig. 1). ‘Blue sky’, ‘S-1’, and ‘Fairy eye’ are lacecap cultivars. ‘BM-1’ and ‘SM-1’ are inflorescence-type mutants of ‘Blue sky’ and ‘S-1’, respectively, and produce hortensia inflorescences (Uemachi et al., 2009). On the Shinshu University experimental farm, all plants were grown in 32.5-cm-diameter pots filled with 8 L of medium composed of 75% Metro Mix 250 (SunGro Horticulture Distribution, USA) and 25% vermiculite (v/v) (Asahi Kogyo, Japan). Plants were grown from December 2014 to March 2015 in a greenhouse heated above 0°C and were grown in a greenhouse without heating. Plants were grown under full sunlight from October 2014 to May 2015 and were grown under 50% sunlight from June to July 2015.

Harvest and preparation of cut flowers

From June to July 2015, five to six cut flowers with stems left approximately 60-cm-long were harvested when approximately 80% of the decorative florets in the inflorescence had developed the cultivar-specific color. All leaves were immediately removed.

The ends of the cut flower stems were recut under distilled water just after the harvest, leaving 50-cm-long stems. Diameters of the recut stem ends were measured. All cut flowers were kept in plastic bottles filled with 1 L of distilled water. The bottle was loosely sealed with Parafilm (Pechiney Plastic Packaging Company, Chicago, USA) to suppress evaporation from the water surface. Cut flowers were placed in an environmentally controlled room held at 25 ± 2°C and 50 ± 5% relative humidity, and were maintained under a 12-h photoperiod at a light intensity of 10 μmol·m⁻²·s⁻¹ provided by daylight fluorescent tubes (FL40SSN/37; Toshiba Lighting and Technology Co., Yokosuka, Japan).

Transpirations and vase lives of cut flowers with lacecap and hortensia inflorescences

‘Blue sky’ and ‘S-1’ with lacecap inflorescences and their inflorescence-type mutants, ‘BM-1’ and ‘SM-1’, with the hortensia inflorescences were used (Uemachi et al., 2009).

Just after the preparation of the cut flowers, the total mass of the cut flowers, distilled water, and bottle was recorded. The mass was recorded in the same manner at the same time on the following day, and the daily transpiration rate from the cut flower was defined as the decrease in mass in this time period.

Vase life was terminated when sepal browning or sepal wilting became apparent on approximately 80% of the decorative florets in an inflorescence. Decorative

and non-decorative florets were counted after the end of the vase life. Viable non-decorative florets were counted, and non-decorative florets that had undergone necrosis were not counted. In most cut hydrangea flowers, the non-decorative florets were viable beyond the end of the vase life, with the exception of those that had undergone necrosis until the cut flower harvest. Thus, only viable non-decorative florets that contributed to transpiration from the cut flowers were counted.

**Thermal imaging of cut flowers with lacecap and hortensia inflorescences**

On the day after harvest, a thermal image of one cut flower from each of ‘Blue sky’ and ‘BM-1’ was recorded. Thermal images were obtained using a Testo 875–2 thermal camera (Testo AG, Lenzkirch, Germany) in the environmentally controlled room described above.

**Estimation of transpirations from non-decorative florets in lacecap inflorescences and vase lives of non-decorative florets-removed cut flowers**

Two hydrangea cultivars with lacecap inflorescence (‘Blue sky’ and ‘Fairy eye’) were used. ‘Blue sky’ is a single-flowered cultivar, and ‘Fairy eye’ is a double-flowered cultivar.

The transpiration from the non-decorative florets was estimated by comparing the level of transpiration from cut flowers with and without the non-decorative florets. Just after the preparation of the cut flowers, the total mass of the cut flowers with non-decorative florets (intact cut flowers), distilled water, and bottle was recorded. The mass was recorded in the same manner at the same time on the following day, and the daily transpiration rate from the intact cut flower was defined as the decrease in mass in this time period (transpiration in the first day). Following the mass measurement on the day after harvest, all non-decorative florets were removed, and the total mass of the cut flowers, distilled water, and bottle was recorded again. The mass was then recorded at the same time on the following day. The transpiration per non-decorative florets-removed cut flowers was defined as the decrease in mass between the second and third days after harvest (transpiration in the second day). The difference in transpirations between the first and second days was estimated as the transpiration from the non-decorative florets. The transpiration from cut flowers with non-decorative florets on each day was measured as a control. The termination of vase life and counting of florets were conducted as described above.

**Statistical analysis**

Data collected for the vase life and transpiration per cut flower were analyzed by Welch’s t-test.

**Results**

**Vase life and transpiration from cut flowers with lacecap and hortensia inflorescences**

The cut flower characteristics are shown in Table 1. All the cut flowers with lacecap inflorescence had fewer decorative florets and more non-decorative florets, as well as more florets in total, than those with hortensia inflorescences. Cut flowers of the ‘SM-1’, mutant with hortensia inflorescences, frequently exhibited abscissions of the non-decorative florets before harvest and had a lower number of non-decorative florets. This resulted in a relatively large difference in the total number of florets between the original cultivar and mutant compared to the difference between ‘Blue sky’ and ‘BM-1’. The stem diameters were almost identical between the original cultivars and their mutants. There was no significant difference in the transpiration levels or vase lives of ‘Blue sky’ and ‘BM-1’ (Fig. 2). On the other hand, the hortensia cultivar ‘SM-1’ tended to exhibit lower transpiration and exhibited significantly longer vase life (approximately 3 days) than its hortensia mutant ‘SM-1’.

**Thermal imaging of cut flowers with lacecap and hortensia inflorescences**

Thermal imaging showed that the non-decorative floret cluster of ‘Blue sky’ exhibited a lower temperature than the decorative sepals of ‘Blue sky’ and ‘BM-1’ (Fig. 3). Clusters of the petals, stamens, and pistils of the decorative florets also exhibited lower temperatures than the decorative sepals in both ‘Blue sky’ and ‘BM-1’.

**Table 1.** Inflorescence type, number of decorative florets, number of non-decorative florets, total number of florets, and stem diameter in each cultivar and its mutant.

<table>
<thead>
<tr>
<th>Cultivars and mutants</th>
<th>Inflorescence type</th>
<th>Number of decorative florets</th>
<th>Number of non-decorative florets</th>
<th>Total number of florets</th>
<th>Diameter of stem end (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue sky</td>
<td>Lacecap</td>
<td>12 ± 1&lt;sup&gt;x&lt;/sup&gt;</td>
<td>701 ± 68</td>
<td>713 ± 50</td>
<td>9.9 ± 0.7</td>
</tr>
<tr>
<td>BM-1 (mutant)</td>
<td>Hortensia</td>
<td>259 ± 15</td>
<td>272 ± 50</td>
<td>531 ± 69</td>
<td>9.4 ± 0.6</td>
</tr>
<tr>
<td>S-1</td>
<td>Lacecap</td>
<td>14 ± 2</td>
<td>501 ± 22</td>
<td>514 ± 21</td>
<td>8.3 ± 0.4</td>
</tr>
<tr>
<td>SM-1 (mutant)</td>
<td>Hortensia</td>
<td>160 ± 32</td>
<td>24 ± 6</td>
<td>184 ± 26</td>
<td>7.8 ± 0.5</td>
</tr>
</tbody>
</table>

<sup>x</sup> Numbers of viable non-decorative florets were counted.

<sup>y</sup> Number of decorative florets and viable non-decorative florets.

<sup>z</sup> The values are the means±SE (n=5–6).
Transpiration from non-decorative florets in cut flowers with lacecap inflorescences

The cut flower characteristics of the intact and non-decorative florets-removed cut flowers are shown in Table 2. The numbers of decorative florets and stem diameters were almost identical between those cut flowers. Cut flowers of ‘Fairy eye’ had fewer non-decorative florets than ‘Blue sky’. Removal of the non-decorative florets on the second day significantly reduced the transpiration per cut flower (Table 3). Estimated transpirations from the non-decorative florets of ‘Blue sky’ and ‘Fairy eye’ were approximately 34.0 and 9.2 g·day$^{-1}$, and they were equivalent to 61.8 and 39.7%, respectively, of the transpiration from the intact cut flowers on the first day. There was no significant difference in transpiration between the first and second days for the intact cut flowers that were used as a control.

Vase lives of non-decorative florets-removed and intact cut flowers with lacecap inflorescences

Non-decorative florets-removed cut flowers of ‘Blue sky’ and ‘Fairy eye’ exhibited 18 days and 22 days longer vase lives than the intact cut flowers, respectively, and the differences were significant at $P < 0.01$ (‘Blue sky’) and 0.05 (‘Fairy eye’), respectively (Fig. 4). The cut flowers of ‘Fairy eye’ tended to exhibit longer vase lives than ‘Blue sky’ in both of control and non-decorative florets-removal treatments.

Discussion

The vase life of cut hydrangea flowers with hortensia inflorescences harvested at the fresh-stage can be extended by reducing the number of decorative florets (Kitamura and Ueno, 2015). It has been suggested that these treatments extend the vase life by reducing the level of transpiration from the cut flowers. Thus, we hypothesized that cut flowers with lacecap inflorescences would exhibit lower transpirations and longer vase lives than those with hortensia inflorescences. However, the present study indicated that the cut flowers with lacecap inflorescences do not necessarily exhibit a longer vase life than cut flowers with hortensia inflorescences. This suggests that the factor that regulates the transpiration from lacecap inflorescences is not only the number of flowers.
decorative florets. Thermal imaging of ‘Blue sky’ and ‘BM-1’ indicated that transpiration from the non-decorative floret clusters is one of the major components of total transpiration from lacecap inflorescences. In the decorative florets, the petals, stamens, and pistils also exhibited lower temperatures than decorative sepals, suggesting that they also make a large contribution to the transpiration from the non-decorative florets (Fig. 3). ‘BM-1’ cut flowers had approximately 250 more decorative florets than ‘Blue sky’; however, the transpiration from the cut flowers was almost identical between them. This suggested that the non-decorative florets, ‘Blue sky’ had 430 more non-decorative florets than ‘BM-1’, act as a major factor that regulates the transpiration from lacecap inflorescence, and the transpiration from 250 decorative florets was almost equal to that from 430 non-decorative florets in these original cultivars and mutants (Table 1). Higher transpiration from the decorative florets was due to the transpiration from the decorative sepals in addition to that from the non-decorative floral organs. The almost identical vase lives of ‘Blue sky’ and ‘BM-1’ cut flowers can be attributed to the almost identical transpiration from them. The cut flowers of ‘SM-1’ had markedly fewer non-decorative florets than ‘S-1’ (Table 1), and this resulted in the relatively large difference in the total number of florets. The lower number of total florets in ‘SM-1’ cut flowers could be attributed to the lower transpiration and the significantly longer vase lives than ‘S-1’ cut flowers.

Table 2. Number of florets and stem diameter in intact and non-decorative florets-removed cut flowers.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Flower type</th>
<th>Treatment</th>
<th>Number of decorative florets</th>
<th>Number of non-decorative florets⁷</th>
<th>Diameter of stem end (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue sky</td>
<td>Single</td>
<td>Intact</td>
<td>12 ± 1y</td>
<td>701 ± 68</td>
<td>9.9 ± 0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Removal of non-decorative florets</td>
<td>14 ± 1</td>
<td>—</td>
<td>10.7 ± 0.2</td>
</tr>
<tr>
<td>Fairy eye</td>
<td>Double</td>
<td>Intact</td>
<td>15 ± 2</td>
<td>160 ± 16</td>
<td>6.2 ± 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Removal of non-decorative florets</td>
<td>16 ± 2</td>
<td>—</td>
<td>6.6 ± 0.3</td>
</tr>
</tbody>
</table>

* Numbers of viable non-decorative florets were counted.

Table 3. Transpiration from intact and non-decorative florets-removed cut flowers and estimated transpiration from non-decorative florets.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Transpiration from control intact cut flowers (g·day⁻¹)</th>
<th>Transpiration from non-decorative florets-removed cut flowers (g·day⁻¹)</th>
<th>Estimated transpiration from non-decorative florets (%)w</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st day</td>
<td>2nd day</td>
<td>Welch’s t-test⁶</td>
</tr>
<tr>
<td>Blue sky</td>
<td>41.3</td>
<td>46.9</td>
<td>NS</td>
</tr>
<tr>
<td>Fairy eye</td>
<td>21.3</td>
<td>21.0</td>
<td>NS</td>
</tr>
</tbody>
</table>

* Significance of difference between the 1st and 2nd days was analyzed. NS, *, and ** indicate non-significant, significant at P<0.05, and significant at P<0.01 (n=4–6).

Table 4. The vase life of intact and non-decorative florets-removed cut flowers. * and ** indicate significant difference between the intact and non-decorative florets-removed cut hydrangea flowers at P<0.05 and P<0.01 by Welch’s t-test. Values are the means ± SE (n=5–6).

Fig. 4. The vase life of intact and non-decorative florets-removed cut flowers. * and ** indicate significant difference between the intact and non-decorative florets-removed cut hydrangea flowers at P<0.05 and P<0.01 by Welch’s t-test. Values are the means ± SE (n=5–6).
sky’ have petals, stamens, and pistils other than decorative sepals; however, those of ‘Fairy eye’ have only pistils other than decorative sepals, and transpiration from the the petals and stamens may raise the transpiration from the decorative florets of ‘Blue sky’. To confirm this hypothesis, further studies such as a comparison of the area of the decorative sepals should be conducted.

In roses and carnations, transpiration from the flower accounts for 20 and 27% of transpiration from the cut flower, respectively (Carpenter and Rasmussen, 1974). In anthurium, transpiration from the spathe largely contributes to total transpiration from the cut flowers (Mujaffar and Sankat, 2003; Paull and Goo, 1985). These studies investigated the transpiration from the floral organs, including decorative organs such as the decorative petals and spathe. The non-decorative florets of hydrangeas also have petals, but, they are markedly smaller than the decorative sepals and are non-decorative organs. Few studies have previously investigated the transpiration from non-decorative floral organs. In anthurium, transpiration from the spadix, the cluster of the non-decorative florets, contributes to total transpiration levels from the cut flower together with the spathe (Mujaffar and Sankat, 2003; Paull and Goo, 1985). Transpiration is one of the key factors that determine water balance in cut flowers (Ichimura, 2010).

The present study suggests that transpiration from the non-decorative floral organs such as the petals, stamens, and pistils should be considered as an important factor in regulating the water balance of cut flowers.

The effect of transpiration from flowers on the vase life of cut flowers has previously been studied in some ornamental plants. In anthurium, the suppression of transpiration from the spathe has been found to extend the vase life of the cut flowers (Mujaffar and Sankat, 2003; Paull and Goo, 1985). Our previous research indicated the large contribution of transpiration from decorative florets to the vase life of cut hydrangea flowers (Kitamura and Ueno, 2015). In the present study, removal of the non-decorative florets extended the vase life of the cut flowers with lacecap inflorescences (Fig. 4). Wilted cut hydrangea flowers can often be revived by recutting the stem end in water (Unpublished data), which indicates that the wilting of the cut hydrangea flower is often caused by vessel occlusion that disrupts the water balance (Loubaud and van Doorn, 2004; van Doorn and Cruz, 2000; van Doorn et al., 1989). The removal of the non-decorative florets reduces the amount of water required to maintain the water balance of the cut flowers and can improve their tolerance to vessel occlusion. Therefore, the application of anti-transpirants, materials that coat the surface of the cut flower, on the non-decorative floret clusters would be useful to extend the vase life of cut hydrangea flowers with the lacecap inflorescences.

In the present study, we revealed the effect of transpiration from non-decorative florets on the vase life of cut hydrangea flowers with lacecap inflorescences. We conclude that the use of cut flowers that do not bear too many non-decorative florets and/or treatments that suppress transpiration from the non-decorative florets would be effective in extending the vase life of cut hydrangea flowers with lacecap inflorescences. In regard to the hortensia hydrangea cultivars, further research is required to reveal the contribution of transpirations from the petals, stamens, and pistils of the non-decorative and decorative florets toward the total transpiration and vase life of the cut flowers.

**Literature Cited**


