Effects of photoperiod on growth and flowering of *Chrysanthemum morifolium* Ramat cv. Reagan Sunny
(Kesan kefotokalaan terhadap pertumbuhan dan pembungaan *Chrysanthemum morifolium* Ramat kultivar Reagan Sunny)

S. Ab. Kahar*

Key words: *Chrysanthemum morifolium*, photoperiod, growth, flowering, flower quality

Abstract

*Chrysanthemum morifolium* plants cv. Reagan Sunny were exposed to different photoperiod at two stages of flowering namely flower bud initiation and flower bud development. The photoperiods tested were natural photoperiod (control), 8 h daylight with 4 h incandescent (12PP), 8 h daylight with 2 h incandescent (10PP), and 8 h daylight (8PP). The growth, time of different stages of flowering and flower quality were recorded. The growth was not obviously influenced by photoperiod at both stages of exposure. Flower initiation was promoted by 8 h photoperiod and delayed by incandescent light at the end of 8 h daylight. Buds formed under treatment with 4 h incandescent were not able to develop into flowers. Further bud development and the overall time of flowering were also delayed with 8 h photoperiod. Exposing plants to photoperiods during bud development delayed bud development, and also flowering if given 4 h incandescent. Despite delaying flowering, the 2 h incandescent at the end of 8 h daylight period caused synchronization of flowering within a plant. Flower quality also did not obviously improve by shortening photoperiod.

Introduction

Most chrysanthemum cultivars are developed to suit the cultivation in the mild climatic regions, such as in the temperate countries or in the highlands of tropics. However there are cultivars that can tolerate high temperature conditions (Kofranek 1980). Ros Anita (2001) also reported that some cut flower cultivars have the potential to be grown in lowland tropics, but the flower quality does not match the highlands grown chrysanthemums.

Chrysanthemums are short-day (SD) plants. The natural photoperiod of about 12 h such as in Malaysia is suitable for good flowering of most cultivars (Kofranek 1980). However, the high temperature (27–34 °C), which are far higher than optimum, will affect flowering (delay in time) and quality (poor architecture, discoloration and sometimes mull-formed) of cut flowers (Whealy et al. 1987; Karlsson et al. 1989; Pearson et al. 1993).

There are strong interaction effects of temperature and photoperiod on flowering of many species. *Aechynanthus* ‘Koral’ responses as day neutral under 18 °C, but as long day (LD) at 24 °C (Whitton and Healy 1991). The June bearing strawberry, a facultative SD plant, low temperature (6 °C) enables the plants to initiate flower at 24 h photoperiod, but at...
higher temperature the critical day length is 11.5 h (Heide 1977). For the everbearing strawberry, temperature of 10 °C or less, the plants response as day natural, whereas at intermediate and high (27 °C) the plants response as quantitative and qualitative long day respectively (Sonsteby and Heide 2007).

In most photoperiodic sensitive plants, flowering occurs within a range of critical photoperiod, but it has been shown that a favourable temperature and optimum photoperiod accelerated flowering as compared to the other treatments within the critical limit (Adams et al. 1997; Adams et al. 1999). It has been also shown that, the sensitivity of plants to temperature and photoperiod dependent on stages of development (Harbaugh 1995; Wang et al. 1998). Therefore flowering of chrysanthemum under high temperature might be improved by shortening the 12 h natural photoperiod when imposed at the appropriate stages. This study was conducted to verify this hypothesis.

Materials and methods
Rooted cuttings of Chrysanthemum morifolium cv. Reagan Sunny from Van Der Kamp (M) Sdn. Bhd. were planted in 20 cm containers. The planting media consisted of top soil, organic matter and sand at the ratio of 2:1:1 (v/v basis). About 2 kg Ground Magnesium Limestone was incorporated for every cubic meter of medium. One plant was planted on each pot and each plant was supported by a wooden stake to get an up-right growth. Pots were placed on the ground and spaced 20 cm apart.

Immediately after planting, night interruption lighting was provided with incandescent bulbs from 10 p.m. to 2 a.m. to obtain long-day condition. The plants were fertilized with a compound fertilizer containing 15% N, 15% P₂O₅ and 15% K₂O at planting and 5 weeks after planting. The plants were irrigated twice daily using an overhead sprinkler system.

Five weeks after establishment in the containers, 240 uniform plants were selected then divided into two groups (120 plants for each group). In the first group (experiment 1), the plants (non-induced plants) were exposed to different photoperiod treatments for floral induction. In the second group (Experiment 2), the plants were placed under natural short-day condition and only after flower bud was visible (20 days) then the plants were exposed to different photoperiod treatments.

The experiments were laid in a Randomized Complete Block Design (RCBD) with three replications. Each replication consisted of 10 plants. Four photoperiod treatments were tested; T1: natural photoperiod (control); T2: 8 h daylight and 4 h incandescent (2PP); T3: 8 h daylight and 2 h incandescent (10PP); T4: 8 hours daylight (8PP). The 8 h daylight for T2, T3 and T4, was obtained by imposing black out with black cloth suspended on wooden frame from 4 p.m. until 8 a.m. The black cloth was opened daily between 8 a.m. and 4 p.m. Two incandescent bulbs were fixed on each frame for day extension lighting. Each frame measured 1.0 m x 1.4 m and 1.2 m in height.

Time of flowering
Karlsson et al. (1989) defined four stages of flowering, namely (I) visible bud (VB), (II) disbud (DB), (III) showing colour (SC) and (IV) bloom (B). In this study, recordings of time were only done on three stages (stages II and III were combined). The time taken from SD to VB, VB to SC and SC to B and overall time from SD to harvesting were determined. Measurements on time of flowering were made on all for plants.

Growth analysis
At harvesting stage, three plants were selected from each plot for growth analysis. The stems were cut at growing medium level. The length and diameter of stem, number of nodes, the number and length of flower stalks, spray diameter, the number of buds and flowers were determined.
Results

Growth

During flower bud initiation, only plant height was significantly \((p < 0.05)\) affected by photoperiod (Table 1). Generally, treatments of 8 h daylight with and without incandescent light (12PP and 10PP) have greater plant height as compared to treatment with natural photoperiod (control), but the difference between 10PP and control was not significant. The effects of different photoperiods on total leaf area and dry weight of all components were not significant.

Vase life

At harvesting stage, three plants were selected for vase life determination. The stems were cut at 45 cm, and all the cut stems were placed in solution contain Sprite under room conditions. The bases of stems were cut at alternate days to prevent from blockage. Vase life of the flower was determined when the first flower wilted. Measurement of flower diameter was also done on these plants.

Data analysis

Statistical analysis was performed using SAS and treatment means were compared using Duncan Multiple Range Test (DMRT).

Table 1. Growth of *Chrysanthemum morifolium* under different photoperiod during flower bud initiation and development

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>Total leaf area (cm²)</th>
<th>Plant dry weight (g)</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Leaf</td>
<td>Stem</td>
</tr>
<tr>
<td>Bud initiation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1: Natural photoperiod (control)</td>
<td>67.39b</td>
<td>1052a</td>
<td>6.00a</td>
<td>11.70a</td>
</tr>
<tr>
<td>T2: 8 h daylight, 4 hours incandescent light (12PP)</td>
<td>69.86a</td>
<td>-Y</td>
<td>-Y</td>
<td>-Y</td>
</tr>
<tr>
<td>T3: 8 h daylight, 2 h incandescent light (910PP)</td>
<td>68.23b</td>
<td>945a</td>
<td>5.41a</td>
<td>10.99a</td>
</tr>
<tr>
<td>T4: 8 h daylight (8PP) F-test</td>
<td>69.91a</td>
<td>990a</td>
<td>5.64a</td>
<td>11.28a</td>
</tr>
<tr>
<td>Bud development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1: Natural photoperiod (control)</td>
<td>67.45c</td>
<td>1022a</td>
<td>5.87a</td>
<td>12.31a</td>
</tr>
<tr>
<td>T2: 8 h daylight, 4 h incandescent light (12PP)</td>
<td>68.99b</td>
<td>985ab</td>
<td>5.46ab</td>
<td>12.86a</td>
</tr>
<tr>
<td>T3: 8 h daylight, 2 h incandescent light (10PP)</td>
<td>70.29a</td>
<td>1067a</td>
<td>6.01a</td>
<td>12.38a</td>
</tr>
<tr>
<td>T4: 8 h daylight (8PP) F-test</td>
<td>66.67c</td>
<td>875b</td>
<td>4.67b</td>
<td>10.40b</td>
</tr>
</tbody>
</table>

Mean values in each column with the same letter are not significantly different at \(p < 0.05\) according to DMRT

ns = Non-significant, *Significant at \(p < 0.05\), **Significant at \(p < 0.01\), ***Significant at \(p < 0.001\)

\(^Y\) Plants did not reach the stage for data collection

Plants were then separated into major components, leaves, stems, flower stalks and flowers. Dry weight of each component was determined after drying the sample at 80 °C in a force-draft oven for 48 h.
under 8PP as compared to other treatments. Similarly, the dry weight of leaves and stems, where significant reduction ($p < 0.05$), were found under 8PP. The dry weight of flower stalk was increased with day extension with incandescent light, the longer the duration (12PP) the greater the weight. However, flower dry weight was not significantly affected by photoperiod.

**Time of flowering**

The effects of different photoperiod treatments during flower initiation on time to VB (from beginning of SD), VB to SC, SC to bloom and the overall flowering time (SD to harvest) are summarized in Table 2. Eight hours photoperiod (8PP) did not reduce time to VB as compared to the control; both took place at 20 days. The extension lighting such as in 12PP and 10PP treatments delayed time of VB for 14 and 7 days respectively.

Different photoperiods also influenced the development of initiated flower buds. Flower buds under 12PP were not able to develop, where all buds turned into crown buds (*Plate 1*). Bud showing colour (SC) was hastened under 10PP, but delayed significantly ($p < 0.05$) at 8PP. The time from SC to bloom was less effected, but there was a significant difference between the 10PP and 8PP. The overall time of flowering (SD to harvest) too was delayed by and most obviously at 8PP.

A slight difference on response to photoperiod when imposed during bud development stage (after bud formation), was observed (*Table 2*). Buds under all treatments were able to develop (*Plate 2*). Time from VB to SC was significantly delayed ($p < 0.05$) under 8 h daylight with and without incandescent light, and the longer the duration of incandescent, the longer the time is needed. Time from SC to bloom delayed significantly ($p < 0.01$) with 4 h incandescent (12PP). The overall time of flowering was only differed significantly ($p < 0.05$) under 12PP compared to the rest of treatments.

**Synchronization of flower development**

Photoperiod has a significant effect ($p < 0.05$) on the synchronization of bud development within a plant. When different photoperiods were imposed at the bud initiation stage, the

---

### Table 2. Time of flowering of *Chrysanthemum morifolium* under different photoperiods during flower bud initiation and development

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Days to visible bud</th>
<th>Visible bud to showing colour</th>
<th>Showing colour to bloom</th>
<th>Days to harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bud initiation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1: Natural photoperiod</td>
<td>20.1c</td>
<td>26.2b</td>
<td>22.1ab</td>
<td>68b</td>
</tr>
<tr>
<td>T2: 8 h daylight, 4 h incandescent light (12PP)</td>
<td>44.2a</td>
<td>.v</td>
<td>.v</td>
<td>.v</td>
</tr>
<tr>
<td>T3: 8 h daylight, 2 h incandescent light (10PP)</td>
<td>27.0b</td>
<td>24.1c</td>
<td>20.2b</td>
<td>71ab</td>
</tr>
<tr>
<td>T4: 8 h daylight (8PP)</td>
<td>20.0c</td>
<td>29.0a</td>
<td>24.0a</td>
<td>73a</td>
</tr>
<tr>
<td>F-test</td>
<td>***</td>
<td>**</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Bud development</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1: Natural photoperiod</td>
<td>-</td>
<td>27.1c</td>
<td>22.0b</td>
<td>69.1b</td>
</tr>
<tr>
<td>T2: 8 h daylight, 4 h incandescent light (12PP)</td>
<td>-</td>
<td>34.4a</td>
<td>33.6a</td>
<td>88.0a</td>
</tr>
<tr>
<td>T3: 8 h daylight, 2 h incandescent light (10PP)</td>
<td>-</td>
<td>28.6b</td>
<td>22.4b</td>
<td>71.0b</td>
</tr>
<tr>
<td>T4: 8 h daylight (8PP)</td>
<td>-</td>
<td>28.8b</td>
<td>20.2b</td>
<td>69.2b</td>
</tr>
<tr>
<td>F-test</td>
<td>**</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT

*Significant at $p < 0.05$, **Significant at $p < 0.01$, ***Significant at $p < 0.001$

<sup>Y</sup> Plants did not reach the stage for data collection
differences in time of showing colour (SC) buds 1 and 6 were reduced about 2 days from 6.2 days at control to only 4 days at 8PP (Figure 1). Similar trend was observed when different photoperiods were imposed at bud development stage, but with a lesser magnitude.

**Flower quality**

Quality characteristics of the flowers were also influenced by photoperiod at both flower development stages (Table 3). Imposition at flower initiation resulted in significant reduction ($p < 0.05$) of inflorescence and flower diameters, and shelf life at 8PP as compared to control. Similar trend was observed at stalk length, but the difference was not significant. However, there was an opposite trend showed on the number of bract, where there was a slight increase at 8PP and significant increase ($p < 0.05$) at 10PP.

The differences in response of flower characteristics were observed when different photoperiods were imposed at bud development stage. Inflorescence diameter and stalk length were not significantly differed between treatments. Flower diameter was significantly ($p < 0.05$) reduced at 8PP. The number of bracts was significantly less ($p < 0.05$) under 12PP. Unlike photoperiod during flower initiation, the longest shelf life was found at 8PP.

**Discussion**

Reduced day length from about 12 h under natural photoperiod to 8 h did not affect much the growth of *C. morifolium* cv. Reagan Sunny especially when plants were exposed to different photoperiods during the

---

**Plate 1. Effects of different photoperiods imposed during bud initiation on flowering of *Chrysanthemum morifolium* cv. Reagan Sunny**

**Plate 2. Effects of different photoperiods imposed during bud development on flowering of *Chrysanthemum morifolium* cv. Reagan Sunny**

**Figure 1. Effects of different photoperiods on flowering synchronization – differences in time SC buds 1 and 6**

---

*S. Ab. Kahar*
Effect of photoperiod on flowering of chrysanthemum

Table 3. Flower quality of *Chrysanthemum morifolium* under different photoperiods during flower bud initiation and development

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Inflorescence diameter (cm)</th>
<th>Stalk length (cm)</th>
<th>Flower diameter (cm)</th>
<th>No. of Bracts</th>
<th>Shelf life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bud initiation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1: Natural photoperiod</td>
<td>11.21ab</td>
<td>10.75a</td>
<td>8.32a</td>
<td>5.83b</td>
<td>13.75a</td>
</tr>
<tr>
<td>T2: 8 h daylight, 4 h incandescent light (2PP)</td>
<td>.2ab</td>
<td>.75a</td>
<td>.82a</td>
<td>.58b</td>
<td>.75a</td>
</tr>
<tr>
<td>T3: 8 hours daylight, 2 h incandescent light (10PP)</td>
<td>12.01a</td>
<td>10.68a</td>
<td>7.66a</td>
<td>7.08a</td>
<td>12.25ab</td>
</tr>
<tr>
<td>T4: 8 h daylight (8PP)</td>
<td>10.38b</td>
<td>9.88a</td>
<td>7.31b</td>
<td>6.25b</td>
<td>9.92b</td>
</tr>
<tr>
<td>F-test</td>
<td>*</td>
<td>ns</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Bud development</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1: Natural photoperiod</td>
<td>10.20a</td>
<td>10.40a</td>
<td>8.35a</td>
<td>5.75ab</td>
<td>12.17ab</td>
</tr>
<tr>
<td>T2: 8 h daylight, 4 h incandescent light (12PP)</td>
<td>10.46a</td>
<td>10.25a</td>
<td>8.26a</td>
<td>5.36b</td>
<td>9.75b</td>
</tr>
<tr>
<td>T3: 8 h daylight, 2 h incandescent light (10PP)</td>
<td>10.59a</td>
<td>9.73a</td>
<td>7.91ab</td>
<td>6.42a</td>
<td>11.00ab</td>
</tr>
<tr>
<td>T4: 8 h daylight (8PP)</td>
<td>11.17a</td>
<td>10.58a</td>
<td>7.43b</td>
<td>6.42a</td>
<td>13.00a</td>
</tr>
<tr>
<td>F-test</td>
<td>ns</td>
<td>ns</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT

 ns = non-significant, *Significant at $p < 0.05$, **Significant at $p < 0.01$, ***Significant at $p < 0.001$

Plants did not reach the stage for data collection

but initiation stage (beginning of inductive short day). The effect of photoperiod on growth was slightly shown when imposed after bud had already formed, although duration of exposure was shorter.

The total leaf and dry weight of leaves and stems were reduced at 8 h photoperiod (8PP) as compared to natural photoperiod. This might be the result of reduced photosynthetic production under short photoperiod (Cockshull and Hughes 1972). However, day extension with incandescent light, which is low in photosynthetically active radiation (PAR) in 12PP and 10PP did not significantly reduce total leaf area and leaves, dry weight of leaves and stems as compared to under natural photoperiod.

Stem height and flower stalk dry weight were only slightly increased with day extension treatments indicating that *C. morifolium* cv. Regan Sunny is less sensitive to end of day extension lighting with far-red light. In Easter lily, 1 h extension with far-red light at the end of 8 h photoperiod increased plant height by 44% to 118% (dependent on cultivars) (Blom et al. 1995). Rajapaske and Kelly (1992) reported that light spectrum during daylight, especially the red to far-red ratio (R:FR) strongly influenced stem elongation of chrysanthemum.

Reduced day length did not shorten time from beginning of SD to flower bud formation (VB) under high temperature conditions. Instead, the 8 h photoperiod (8PP) delayed further bud development and the overall time of flowering. This again may due to less photosynthetic produce under short photoperiod (Cockshull and Hughes 1972).

Similar results have been reported for sweetpotato (Mortley et al. 1996). The increase in temperature about 3 °C under the black cloth during dark period may also cause heat delay (Whealy et al. 1987; Karlsson et al. 1989; Pearson et al. 1993; Erwin et al. 2002). In Arabidopsis thaliana, a long-day plant, a mild increase
in growth temperature, from 23 °C to 27 °C, is equally efficient in flowering induction of plants grown in 8 h short days as they are transferred to 16 h long days (Balasubramaniam et al. 2006).

The day extension with far-red light at both phases of flowering caused the delay in all flowering process. The magnitude of the delay increased as the duration of the extension lighting increased (longer photoperiod). It was as also evident in this study that the sensitivity to photoperiod was greater during the photo inductive stage (bud initiation) as compared to the post inductive stage (bud development). The plants failed to initiate flower buds and flowers with the 4 h of far-red at the end of 8 h light. Similar results have been found on *Eustoma grandiflorum* (Harbaugh 1995) and *Papaver samiferum* (Wang et al. 1998).

Despite the delay in time of flowering imposition to 2 hours far-red light at the end 8 h daylight period (10PP), it caused synchronization flower development. This has been shown by the differences in time of showing colour between bud 1 and bud 6 in a particular plant. Synchronization of flowering is an important criterion determines appearance quality of spray chrysanthemum (Ab. Kahar et al. 2005).

The other aspects of flower quality were not markedly improved by shortening day length. Spray diameter which is normally too large and bracts present in large number under high temperature conditions in the lowland tropics were not reduced by short photoperiod. Instead, flower diameter was negatively affected. The results between the two experiments on vase life were inconsistent. When time of exposure begins at bud initiation stage, the 8 h photoperiod (8PP) negatively affect vase life, less by four days as compared to natural photoperiod. The trend was reversed if different photoperiods were imposed after buds have been formed.

**Conclusion**

The results of the study revealed that shortening the day length from about 12 h under natural photoperiod to 8 h with and without far-red extension lighting did not really improve flowering of time and of *C. morifolium* cv. Reagan Sunny. The only positive effect demonstrated from the study was the flowering synchronization by 2 h day extension lighting. However, shortening photoperiod may improve flowering if conditions under the blackout (black cloth) are controlled, to eliminate the temperature build-up.

**References**


Abstrak


Kualiti bunga pada keseluruhaninya tidak meningkat dengan ketara dengan kefotokalaan yang pendek.

Accepted for publication on 9 May 2008