

## EFFECT OF SCREEN HOUSE MODIFICATION AT FLOWER BUD STADIA ON FLOWER QUALITY OF CHRYSANTHEMUM AT MEDIUM UPLAND ELEVATION

### *Pengaruh Modifikasi Rumah Kasa pada Stadium Kuncup Bunga terhadap Kualitas Krisan di Dataran Menengah*

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#### ABSTRACT

Higher temperature and light intensity at the medium upland elevation decrease the number of blooming flowers, flower diameter, and red color flower intensity of *Chrysanthemum morifolium* compared to that at the high upland elevation. The environmental modification was needed during the flower development phase to improve the quality of chrysanthemum at a medium upland elevation. The study aimed to find the suitable screen house environmental modification for increasing the chrysanthemum quality at the medium upland elevation. The study consisted of two factors. First, environmental modification of a screen house, such as (1) control, (2) the addition of shading net on the rooftop of the screen house, (3) the addition of a misting system in the screen house, and (4) the addition of a combination of shading net on the rooftop and misting system in the screen house. Second, the chrysanthemum varieties, including (1) Yastayuki (white flower), (2) Arosuka Pelangi (yellow flower), and (3) Socakawani (red flower). Experiments were arranged in a completely randomized design with three replications. Data were analyzed by combined ANOVA. The results showed that either the addition of a shading net or misting system reduced the number of flower buds growing. The competition among flower buds was found to be reduced by decreasing the number of flower buds. Consequently, the number and diameter of the blooming flower increased. The addition of a shading net on top of the screen house was the most suitable environmental modification to increase the chrysanthemum quality at the medium upland elevation.

**Keywords:** Chrysanthemum, environmental modification, land elevation, misting system, shading net

#### ABSTRAK

Peningkatan suhu dan intensitas cahaya yang tinggi di dataran menengah menurunkan jumlah bunga, ukuran diameter bunga, dan intensitas warna merah bunga *Chrysanthemum morifolium* dibandingkan dengan di dataran tinggi. Modifikasi lingkungan diperlukan selama perkembangan bunga untuk memperbaiki kualitas krisan di dataran menengah. Penelitian ini bertujuan untuk mendapatkan modifikasi lingkungan yang sesuai untuk meningkatkan kualitas krisan di

dataran menengah. Penelitian terdiri atas dua faktor. Faktor pertama ialah jenis modifikasi lingkungan rumah lindung, yaitu (1) kontrol, (2) penambahan paranet di atas rumah lindung, (3) penambahan pengabutan di dalam rumah lindung, dan (4) penambahan paranet di atas rumah lindung dan sistem pengabutan dalam rumah lindung. Faktor kedua ialah varietas krisan, yakni (1) Yastayuki (bunga putih), (2) Arosuka Pelangi (bunga kuning), dan Socakawani (bunga merah). Perlakuan disusun menggunakan rancangan acak kelompok dengan tiga ulangan. Data dianalisis menggunakan ANOVA gabungan. Hasil penelitian menunjukkan bahwa penambahan paranet maupun sistem pengabutan mengurangi pertumbuhan jumlah kuncup bunga sehingga mengurangi kompetisi antarkuncup bunga. Pengurangan kuncup bunga menyebabkan jumlah bunga mekar dan ukuran diameter bunga meningkat. Penambahan paranet di atas rumah kasa merupakan modifikasi lingkungan terbaik untuk meningkatkan kualitas krisan di dataran menengah.

**Kata kunci:** Chrysanthemum, modifikasi lingkungan, ketinggian tempat, paranet, sistem pengabutan

#### INTRODUCTION

Chrysanthemum is one of the ornamental plants that has a high economic value in the world including in Indonesia. The demand for chrysanthemums in 2007-2016 increased about 26.06% every year (Hayati et al. 2019). The extensification of chrysanthemum production from the highland to the medium land was needed to cope the increasing chrysanthemum consumption

Light intensity, temperature, and relative humidity required by chrysanthemum in highland were 16,678 Lux, 24.1 °C, and 81.2%, respectively (Shintiavira et al. 2019). However, lower altitude caused an increase in temperature and light intensity (Sanjaya et al. 2018). These conditions would reduce the quality of chrysanthemum. The low quality aspects of chrysanthemum were decreasing the number of

blooming flowers and diameter of the blooming flower, such as in Yastayuki, Arosuka Pelangi, and Socakawani varieties. Furthermore, there was the decrease in red flower color intensity (Shintiavira et al. 2019).

The flower quality reduction as the result from the rate of respiration was higher than the rate of photosynthesis (Post and Lacey 1953). Janka et al. (2015) reported that maximum net photosynthesis of the 'Coral Charm' chrysanthemum was reached at 24-28 °C with light intensity below the saturation point of light. The net photosynthesis decreased at above 32 °C, which was combined with the high light intensity. These conditions caused the reduction of assimilate rate and hormone translocation for flower development (Su et al. 2001) respectively. Treatments included warm control (30/25 °C day/night, non-flowering. In addition, a day/night temperature up to 35/20 °C would reduce the intensity of the red color on chrysanthemum 'Relance' (Huh et al. 2008). Meanwhile, according to Shintiavira et al. (2019) light intensity, temperature, and relative humidity in medium land were 26,240 Lux, 29.3 °C, and 76.3%, respectively.

Expanding the cultivation area of chrysanthemum in medium land was chosen because environmental condition in medium land could still be overcome by using environmental modification. Therefore, improving the chrysanthemums' quality in medium land by using environmental modification was needed to create the environment like in highland. The shading net, misting system, and their combination could be used as environmental modification of screen house in medium land.

Ahmed et al. (2016) stated that both shading net or cooling system can reduce ambient temperature in a greenhouse. The shading net with a level of 30-50%, followed by a decrease in light intensity from 60,460 to 30,380 Lux reduced the temperatures up to 2-3 °C. These conditions could increase the number of flowers, flower weight, and red color intensity on chrysanthemums 'Relance' in the subtropical country of Korea (Kim et al. 2004).

As stated by Li et al. (2006) the high pressure of misting systems decreased temperature up to 4 °C. Plaut et al. (1979) have reported that the fogging in a greenhouse could decrease the temperature and increase the relative humidity. These conditions could increase the total anthocyanin content in roses. Meanwhile, Ahmed et al. (2016) stated that cooling system combined with shading net can reduce temperature up to 5 °C. The combination of shading net and misting system systems is expected to reduce ambient temperatures and improve the quality of chrysanthemums in the medium land as well.

The effect of shading net, misting system, and the

combination of both of them to the Yastayuki, Arosuka Pelangi, and Socakawani varieties in medium land has not been reported. The differences in plant characters and flower colors of each variety might have the different effects of environmental modification type. Therefore, the objective of the study was to find the suitable screen house environmental modification for increasing the chrysanthemum quality in medium land.

## MATERIALS AND METHODS

### Plant Materials and Experimental Set-Up

The study was conducted in four screen houses in Samigaluh, Kulonprogo, Special Region of Yogyakarta Province, Indonesia (latitude 07°40' S, longitude 110°12' E, and altitude of 485 m above sea level) from December 2017 to March 2018. The height of screen house was 4 m, the width was 6.5 m, and the length was 12 m. The curved roof was covered by 14% UV filter plastic with thickness of 200 microns. The wall was made from the white screen net in size of 50 mesh.

The plant materials were rooted cuttings of chrysanthemum cv Yastayuki, Arosuka Pelangi, and Socakawani which has 3-4 leaves and the length was 6 cm. These varieties were grown on a bench in the screen house with 100 plants per m<sup>2</sup>. The plants were maintained under a long day condition, for 16 hours with added supplementary lighting at 10.00 pm-02.00 am for 35 days.

The flower bud initiation was occurred at 48-49 days after planting (DAP). When the flower bud size reached 2-5 mm or at 57 DAP, the environmental modifications were started. The disbudding of terminal flower bud and removing of flower bud located 20 cm from the top were applied at 70 DAP.

The basic fertilizer were 5 kg m<sup>-2</sup> goat organic manure, 200 kg ha<sup>-1</sup> urea, 300 kg ha<sup>-1</sup> SP-36, and 350 kg ha<sup>-1</sup> KCL. The additional fertilizers consisted of 2 g l<sup>-1</sup> NPK 16:16:16, 1 g l<sup>-1</sup> red KNO<sub>3</sub>, 2 g l<sup>-1</sup> Gandasil D were given during vegetative phase (0-35 DAP), and 2 g l<sup>-1</sup> NPK, 1 g l<sup>-1</sup> white KNO<sub>3</sub>, 2 g l<sup>-1</sup> Gandasil B were applied during generative phase (36 DAP to harvesting time).

### Research Design

Chrysanthemum 'Yastayuki', 'Arosuka Pelangi', and 'Socakawani' were planted in each type of screen house modification, namely (1) control, (2) the addition of 30% shading net on the top of screen house, (3) the addition of misting system in the screen house, and (4) the combination of both shading net and misting system,

repeated three times. A completely randomized design was used for each screen house.

### **Application of Shading Net on Screen House**

The shading net was made from 100% black monowire flat woven type polyethylene, 24 mesh size or 1.5 hole density per cm<sup>2</sup> or the intensity of the light was transmitted around 30%. The shading net was applied on the UV plastic of the screen house until the walls of the screen house was covered. The shading net was applied when the flower buds are in size of 3-5 mm.

### **Application of Misting System in Screen House**

The hoses of 7 mm diameter were installed inside on the highest roof with a height of 3 m from the ground level and the length of the screen house. The nozzles with a diameter of 0.2 microns were applied in the hoses every one meter. The hoses were connected with a 200 liter capacity water tank equipped with a 100 psi pressure pump for every 20 nozzle points. The time of misting was applied at 09.00 am -03.00 pm cyclically using a timer. The time was 10 minutes on and 10 minutes off.

### **Combination of Shading Net and Misting System in the Screen House**

The combination of shading net and misting system in screen house were applied in same time. The method was the same as the application of shading net and misting system.

## **Observations**

### **Microclimate Parameters**

The environmental temperature, relative humidity, and light intensity were average weekly data. The data were monitored every day at 7.00 am, 9.00 am, 12.00 pm, 3.00 pm, and 5.00 pm.

### **Physiological Parameters**

The physiological parameters such as (1) Leaf surface temperature was calculated using the method of Nielsen et al. (1984); (2) Width of stomata pore aperture and the stomata density were calculated based on the method of Savvides et al. (2012). The stomatal characteristics were observed on the surface of the lower epidermis of the leaves which were smeared with a transparent nail polish then taped to the tape. The results of patches placed

on glass preparations were observed using an Optilab microscope with magnification of 40 and 100 for the width of stomata pore aperture and the stomata density, respectively (Olympus Inc, Japan); (3) Transpiration was calculated by the method of Adewumi et al. (2020). The duration of transpiration was measured using 2 cm x 2 cm the cobalt chloride paper placed under the surface of the lower epidermis of the leaf clamped with transparent mica. When the color of the cobalt chloride paper changed from blue to pink, the period of time was recorded. These parameters were observed at 70 DAP.

### **Plant Growth**

The variables of plant growth were (1) The internode which is the range between the nodes. It was calculated by dividing the height of plant and number of nodes. The internode was calculated at 56, 70, and 105 DAP; (2) Total flower which is a total flower in phase S1-S6 based on the method of Qi et al. (2016). Total flowers were observed at 56, 70, 84, 92, and 105 DAP.

### **Dry Weight Allocation**

The variables of dry weight allocation were (1) leaf dry weight, (2) stem dry weight, (3) flower dry weight, and (4) flower mass ratio which was calculated by dividing flower dry weight and shoot organ dry weight. The shoot organ is leaf dry weight and stem dry weight. The organ dry weight was calculated by separating organ such as root, leaf, stem, and flower. They were dried at 70 °C until constant weight. These parameters were observed at harvesting time.

### **Morphological Quality**

The variables of morphological quality evaluated were (1) harvesting time of 50% flower blooming per plant; (2) total flowers, which was the number of flower buds and blooming flowers located at 20 cm from top; (3) the number of blooming flowers, which was the number of flowers opened at the angle of 45°; (4) the percentage of blooming flowers, calculated by dividing the number of blooming flowers and the total flowers in percent; (5) the diameter of blooming flowers; (6) the length of pedicels, which was the average length of pedicel located at 20 cm from top; and (7) the chroma a and b, measured using the method of Zhao et al. (2016) by using chromameter (Konika, Minolta, Japan). All variables of morphological quality were observed at harvesting time.

## Statistical Analysis

The data were analyzed using combined ANOVA from each screen house. The Duncan Multiple Range Test with alpha 5% was applied if there was a significant difference between treatments. The correlation analysis was used for determining the relationship among variables. All statistical analyses were performed using SAS 9.12 (Abebe 2000).

## RESULTS

### Microclimate Parameters

Table 1 showed that the average of temperature, light intensity, and relative humidity in a screen house as a control was 30.78 °C, 29,810 Lux and 73.16%, respectively. The addition of shading net reduced the temperature and light intensity to 28.30 °C and 16,952 Lux, respectively. Besides that, it increased the relative humidity up to 77.92%. The addition of misting system also reduced the temperature and light intensity to 28.14 °C and 18,083 Lux and increased the relative humidity to 78.70%. The combination of shading net and misting system reduced the temperature to 27.14 °C with a very dramatic decrease in light intensity to 11,355 Lux and increased relative humidity up to 83.50%.

The average of microclimate in Table 1 was resulted from the average of observation on daily microclimates at 07.00 am, 09.00 am, 12.00 pm, 03.00 pm, and 05.00 pm. The Figure 1 showed that all of the environmental modifications of screen house (the addition of shading net, misting system, and combination of both of them) reduced the temperature and intensity efficiently at mid-day (12.00 pm). The shading net reduced the light intensity greater than the misting system during the mid-day (12.00) (Figure 2). There was no significant difference in relative humidity between the shading net or the misting system treatments. However, application of misting system caused a higher relative humidity in the afternoon (05.00 pm) compared to that of shading net. Therefore, the combination of shading net and misting system dramatically reduced the light in the screen house and increased the relative humidity (Figure 3).

### Physiological Parameters

Table 2 showed that the decrease in temperature and light intensity in the modified screen house affected the physiological parameters. Without environment modification of screen house (control), leaf surface temperature of chrysanthemum was 27.76 °C. Application of shading net, misting system, and combination shading net and misting system reduced

Table 1. Microclimate in environmental modification of screen house.

| Treatment           | Air temperature (°C) |       |       | Light intensity (lux) |       |       | Relative humidity (%) |       |       |
|---------------------|----------------------|-------|-------|-----------------------|-------|-------|-----------------------|-------|-------|
|                     | Average              | Max   | Min   | Average               | Max   | Min   | Average               | Max   | Min   |
| Control (C)         | 30.78                | 36.93 | 26.48 | 29819                 | 56357 | 16776 | 73.16                 | 85.30 | 64.72 |
| Shading net 30% (S) | 28.30                | 32.47 | 25.01 | 16952                 | 30390 | 10541 | 77.92                 | 90.30 | 68.79 |
| Misting system (M)  | 28.14                | 32.17 | 24.38 | 18083                 | 39376 | 9284  | 78.70                 | 91.74 | 68.46 |
| S and M             | 27.14                | 32.44 | 23.61 | 11355                 | 25379 | 4588  | 83.05                 | 95.21 | 71.54 |

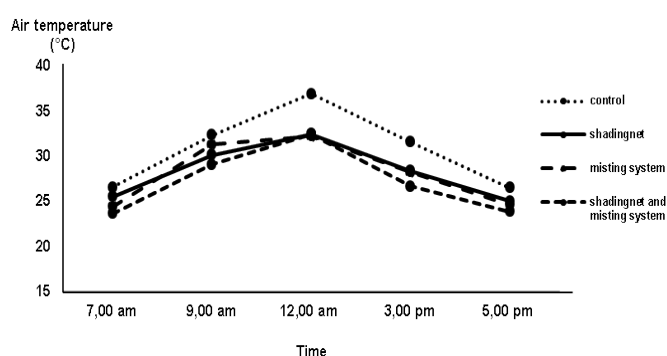


Fig. 1. The average of air temperature(°C) in environment modification of screen house.

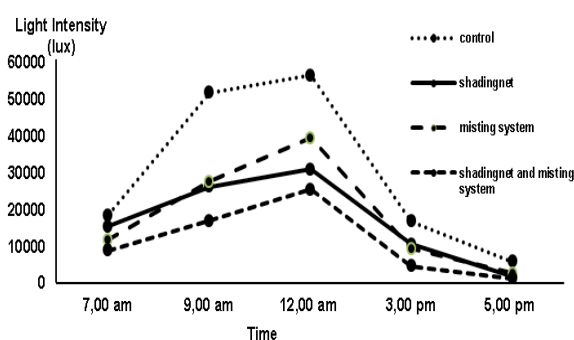


Fig. 2. The average of light intensity in environmental modification of screen house.

**Table 2.** Width of stomata pore aperture, leaf surface temperature, and transpiration of chrysanthemum at 70 DAP in environmental modification of screen house.

| Variables                                         | Environmental modification | Varieties |                 |            | Average  |
|---------------------------------------------------|----------------------------|-----------|-----------------|------------|----------|
|                                                   |                            | Yastayuki | Arosuka Pelangi | Socakawani |          |
| Leaf surface temperature (°C)                     | Control                    | 27.39     | 27.94           | 27.92      | 27.76 a  |
|                                                   | Shading net 30% (S)        | 26.07     | 26.16           | 26.17      | 26.14 b  |
|                                                   | Misting system (M)         | 25.37     | 25.61           | 25.68      | 25.55 c  |
|                                                   | S and M                    | 23.79     | 23.80           | 23.75      | 23.78 d  |
|                                                   | Average                    | 25.65 a   | 25.88 a         | 25.88 a    | (-)      |
| CV = 7.59%                                        |                            |           |                 |            |          |
| Transpiration (s cm <sup>-2</sup> )               | Control                    | 10.46     | 11.25           | 13.87      | 11.86 b  |
|                                                   | Shading net 30% (S)        | 16.79     | 14.04           | 17.67      | 16.17 a  |
|                                                   | Misting system (M)         | 15.25     | 13.16           | 16.37      | 15.08 ab |
|                                                   | S and M                    | 15.79     | 15.12           | 19.31      | 16.74 a  |
|                                                   | Average                    | 14.57 ab  | 13.39 b         | 16.92 a    | (-)      |
| CV = 19.61%                                       |                            |           |                 |            |          |
| Width of stomata pore aperture (μm)               | Control                    | 5.15      | 4.99            | 5.77       | 5.30 a   |
|                                                   | Shading net 30% (S)        | 4.20      | 3.93            | 3.82       | 3.99 b   |
|                                                   | Misting system (M)         | 4.41      | 4.82            | 4.82       | 4.65 ab  |
|                                                   | S and M                    | 3.99      | 3.84            | 4.18       | 4.00 b   |
|                                                   | Average                    | 4.43 a    | 4.40 a          | 4.62 a     | (-)      |
| CV = 13.36%                                       |                            |           |                 |            |          |
| The stomata density (number per mm <sup>2</sup> ) | Control                    | 98.81     | 108.71          | 83.76      | 97.08 a  |
|                                                   | Shading net 30% (S)        | 101.69    | 91.16           | 79.70      | 90.85 ab |
|                                                   | Misting system (M)         | 100.77    | 95.08           | 72.44      | 89.41 ab |
|                                                   | S and M                    | 84.87     | 80.36           | 75.97      | 80.40 b  |
|                                                   | Average                    | 96.54 a   | 93.81 a         | 77.97 a    | (-)      |
| CV = 8.65%                                        |                            |           |                 |            |          |

Note: CV = coefficient of variations.

Means followed the same letter at the same column are not significantly different based on Duncan Multiple Range Test,  $p = 0.05$ .

Sign (-) showed there was not interaction and sign (+) showed there was interaction between the environmental modification and varieties.

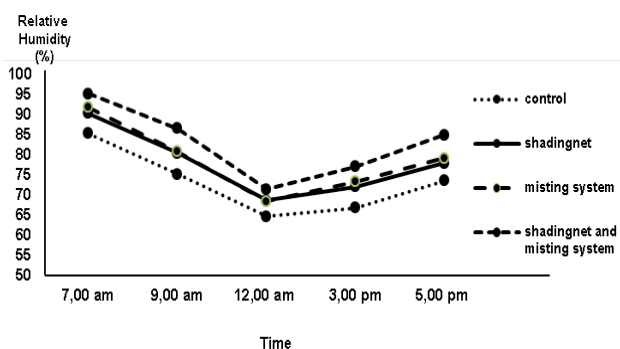


Fig. 3. The average of relative humidity in environmental modification of screen house.

leaf surface temperature of chrysanthemum to 26.14, 25.55, and 23.78 °C, respectively. The decrease in leaf surface temperature of chrysanthemum influenced the leaf transpiration to be slower because the decrease in temperature and light intensity in the screen house reduced width of stomata pore aperture. Without environmental modification (control), width of stomata pore aperture was 5.30 μm. Application of shading net, misting system, and

combination of shading net and misting system reduced width of stomata pore aperture to 3.99, 4.65, and 4.00 μm, respectively. Based on Feller (2006) the leaf surface temperature alteration affected stomata pore aperture that plays a role in controlling the transpiration and leaf cooling.

## Plant Growth

### Internode Elongation

Table 3 showed that the decrease in temperature and light intensity in the modified screen house affected the the growth of internodes. Without environmental modification of screen house (control), the length of internode was 3.10 cm at 70 DAP and 3.59 at 105 DAP. Application of shading net, misting system, and combination of shading net and misting system increased length of internode became 3.19, 3.29, and 3.58 cm at 70 DAP, respectively. Furthermore, these environmental modifications quick up the length of internode became 3.72, 3.90 and 4.21 cm at 105 DAP, respectively.

**Table 3. The growth of internodes of chrysanthemum on environmental modification of screen house.**

| Time of observation | Environmental modification | Varieties |                 |            | Average |
|---------------------|----------------------------|-----------|-----------------|------------|---------|
|                     |                            | Yastayuki | Arosuka Pelangi | Socakawani |         |
| 70 DAP              | Control                    | 3.22      | 2.89            | 3.15       | 3.10 c  |
|                     | Shading net 30% (S)        | 3.24      | 3.05            | 3.30       | 3.19 b  |
|                     | Misting system (M)         | 3.31      | 3.22            | 3.33       | 3.29 b  |
|                     | S and M                    | 3.62      | 3.45            | 3.67       | 3.58 a  |
| CV = 4.05%          | Average                    | 3.35 a    | 3.15 b          | 3.65 a     | (-)     |
| 105 DAP             | Control                    | 3.73 cde  | 3.48 e          | 3.53 de    | 3.59    |
|                     | Shading net 30% (S)        | 3.78 cde  | 3.56 de         | 3.82 cd    | 3.72    |
|                     | Misting system (M)         | 3.80 cde  | 3.96 bc         | 3.94 bc    | 3.90    |
|                     | S and M                    | 4.10 bc   | 3.89 bc         | 4.56 a     | 4.21    |
| CV = 4.30%          | Average                    | 3.87      | 3.72            | 3.97       | (+)     |

Note: CV = coefficient of variations.

Means followed the same letter at the same column are not significantly different based on Duncan Multiple Range Test,  $p = 0.05$ .

Sign (-) showed there was not interaction and sign (+) showed there was interaction between the environmental modification and varieties.

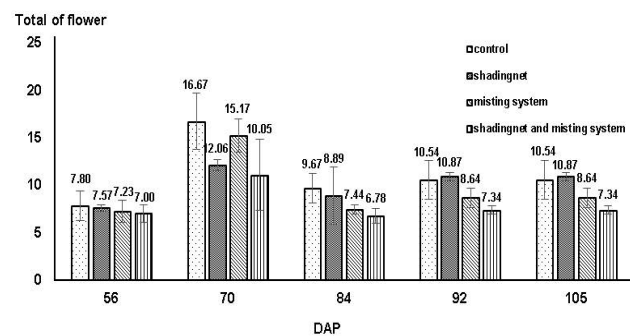


Fig. 4. Total flower of chrysanthemum Yastayuki in environmental modification of screen house.

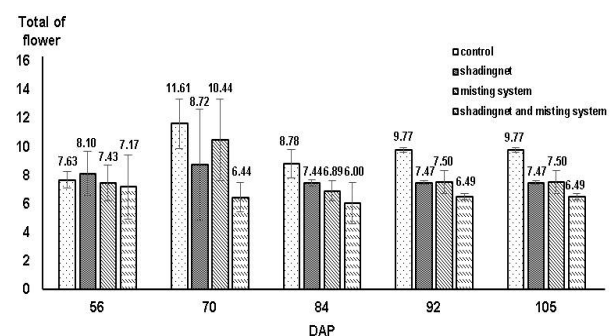


Fig. 5. Total flower of chrysanthemum Arosuka Pelangi in environment modification of screen house.

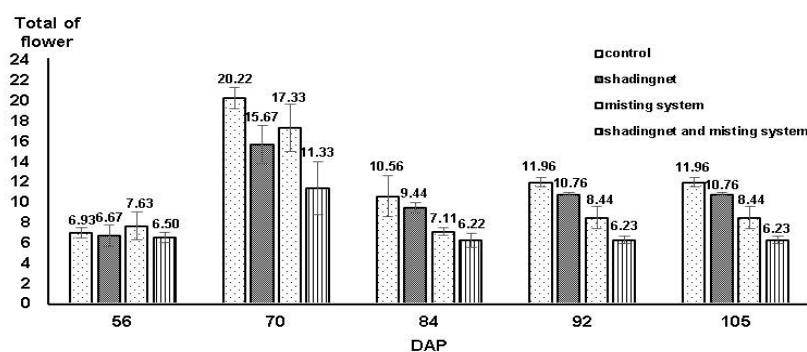


Fig. 6. Total flower of chrysanthemum Socakawani in environmental modification of screen house.

## Flower Bud Growth

The varieties had various branching characters that affected the total flowers per plant. The result showed that the flower bud initiation occurred at 48-49 DAP (data not shown), then one flower bud was developed at 56 DAP. The modification of screen house applied after 56 DAP affected the growth of the number of flower buds at 70 DAP. The number of flower buds at 70 DAP indicated that there was a decrease in the number of flower buds

in all varieties due to the decrease in light intensity. The apical of flower bud and the flower bud located under 20 cm were removed after 70 DAP. There was no significant difference in the number of flower buds due to the application of shading net, compared to the control in all varieties. Meanwhile, there was a decrease in the number of flower buds due to a combination of shading net and misting system in all varieties. It showed that chrysanthemums with longer internodes had an impact on fewer number of flower buds at 84

DAP in all varieties. Furthermore, the flower buds were still increasing by approximately three flower buds at 92 DAP in Yastayuki (figure 4) and Socakawani figure 6). These occurred due to secondary branching growth in pedicels of Yastayuki and Socakawani varieties that grow on axillary buds. However, on the Arosuka Pelangi the number of flower buds did not increase after 70 DAP. This variety has the primary branching type, thus the decrease in light intensity inhibited the growth of axillary buds figure 5).

### Dry Weight Allocation

Table 4 showed that both shading net and combination between shading net and misting system decreased total dry weight of chrysanthemum. Without environmental modification, total dry weight of chrysanthemum was 19.59 g. Application of both shading net and combination between shading net and misting system decreased total dry weight became 17.16 g and 16.46 g. Meanwhile, application of shading net did not affect the total dry

weight. This environmental modification did not change the dry matter allocation for leaves, stem, and flowers. Therefore, both shading net and misting system did not change the flower mass ratio. The flower mass ratio of chrysanthemum in control was 0.140. Meanwhile the flower mass ratio in both shading net and misting system were 0.153 and 0.138, respectively. However, the combination of shading net and misting system reduced the dry matter allocation for the stem and flowers which decreased flower mass ratio (0.133).

### Morphological Quality

Table 5 showed that shading net and misting system increased the number of blooming flowers and flower diameter. The number of blooming flowers was resulted from the decrease in total flower buds. These conditions increased the percentage of blooming flowers. The combination of shading net and misting system could not increase the number of blooming flowers, but it increased the diameter of blooming flowers and the

**Table 4. Leaf dry weight, stem dry weight, flower dry weight, total dry weight, and flower mass ratio of chrysanthemum cultivated in environmental modification of screen house at harvesting time.**

| Variables             | Environment modification | Varieties |                 |            | Average |
|-----------------------|--------------------------|-----------|-----------------|------------|---------|
|                       |                          | Yastayuki | Arosuka Pelangi | Socakawani |         |
| Leaf dry weight (g)   | Control                  | 3.23      | 4.17            | 5.27       | 4.22 a  |
|                       | Shading net 30% (S)      | 3.49      | 3.52            | 5.43       | 4.14 a  |
|                       | Misting system (M)       | 2.70      | 3.61            | 5.79       | 3.70 a  |
|                       | S and M                  | 3.78      | 3.49            | 6.05       | 4.44 a  |
|                       | Average                  | 3.30 b    | 3.70 b          | 5.38 a     | (-)     |
| CV = 23.19%           |                          |           |                 |            |         |
| Stem dry weight (g)   | Control                  | 8.57      | 13.20           | 14.85      | 12.21 a |
|                       | Shading net 30% (S)      | 7.12      | 9.27            | 13.43      | 9.94 b  |
|                       | Misting system (M)       | 8.29      | 11.57           | 17.23      | 12.36 a |
|                       | S and M                  | 7.39      | 8.57            | 13.06      | 9.84 b  |
|                       | Average                  | 7.84 c    | 10.64 b         | 14.72 a    | (-)     |
| CV = 11.08%           |                          |           |                 |            |         |
| Flower dry weight (g) | Control                  | 2.08      | 2.32            | 3.66       | 2.69 a  |
|                       | Shading net 30% (S)      | 2.07      | 2.00            | 3.65       | 2.57 a  |
|                       | Misting system (M)       | 1.92      | 2.25            | 3.43       | 2.53 a  |
|                       | S and M                  | 1.56      | 1.37            | 2.52       | 1.81 b  |
|                       | Average                  | 1.91 b    | 1.98 b          | 3.31 b     | (-)     |
| CV = 14.39%           |                          |           |                 |            |         |
| Total dry weight (g)  | Control                  | 14.20     | 20.29           | 24.30      | 19.59 a |
|                       | Shading net 30% (S)      | 13.07     | 15.37           | 23.05      | 17.16 b |
|                       | Misting system (M)       | 13.33     | 17.86           | 25.87      | 19.02 a |
|                       | S and M                  | 13.07     | 13.68           | 22.64      | 16.46 b |
|                       | Average                  | 13.41 c   | 16.80 b         | 23.91 a    | (-)     |
| CV = 11.61%           |                          |           |                 |            |         |
| Flower mass ratio     | Control                  | 0.149     | 0.117           | 0.155      | 0.140 a |
|                       | Shading net 30% (S)      | 0.167     | 0.135           | 0.162      | 0.153 a |
|                       | Misting system (M)       | 0.150     | 0.129           | 0.153      | 0.138 a |
|                       | S and M                  | 0.122     | 0.102           | 0.114      | 0.113 b |
|                       | Average                  | 0.146 a   | 0.121 b         | 0.141 a    | (-)     |
| CV = 12.18%           |                          |           |                 |            |         |

Note: CV = coefficient of variations.

Means followed the same letter at the same column are not significantly different based on Duncan Multiple Range Test,  $p = 0.05$ .

Sign (-) showed there was no interaction and sign (+) showed there was interaction between the environmental modification and varieties.

**Table 5. Morphological quality of chrysanthemum cultivated in environmental modification of screen house.**

| Variables                             | Environmental modification | Varieties |                 |            | Average   |
|---------------------------------------|----------------------------|-----------|-----------------|------------|-----------|
|                                       |                            | Yastayuki | Arosuka Pelangi | Socakawani |           |
| Plant height (cm)                     | Control                    | 128.17    | 125.00          | 133.25     | 128.81 b  |
|                                       | Shading net 30% (S)        | 127.58    | 126.67          | 141.50     | 131.92 b  |
|                                       | Misting system (M)         | 127.33    | 133.25          | 141.00     | 134.52 ab |
|                                       | S and M                    | 133.17    | 137.75          | 151.25     | 140.72 a  |
| CV = 4.17%                            | Average                    | 129.06 b  | 131.17 b        | 141.75 a   | (-)       |
| Stem diameter (mm)                    | Control                    | 5.12      | 6.19            | 6.89       | 6.06 a    |
|                                       | Shading net 30% (S)        | 4.92      | 5.85            | 6.74       | 5.83 b    |
|                                       | Misting system (M)         | 5.00      | 6.01            | 7.22       | 6.09 a    |
|                                       | S and M                    | 4.75      | 5.63            | 6.99       | 5.79 b    |
| CV = 4.62%                            | Average                    | 4.94 c    | 5.92 b          | 6.97 a     | (-)       |
| The number of blooming flowers        | Control                    | 5.29      | 4.89            | 5.78       | 5.32 b    |
|                                       | Shading net 30% (S)        | 5.86      | 6.98            | 5.82       | 6.22 a    |
|                                       | Misting system (M)         | 6.28      | 6.92            | 6.06       | 6.42 a    |
|                                       | S and M                    | 5.34      | 4.99            | 4.86       | 5.07 b    |
| CV = 12.82%                           | Average                    | 5.69a     | 5.94a           | 5.63a      | (-)       |
| The percentage of blooming lowers (%) | Control                    | 50.80 c   | 49.99 c         | 48.41 c    | 49.73     |
|                                       | Shading net 30% (S)        | 53.92 c   | 93.34 a         | 54.07 c    | 67.15     |
|                                       | Misting system (M)         | 73.60 b   | 91.98 a         | 71.57 b    | 79.14     |
|                                       | S and M                    | 73.16 b   | 76.98 b         | 77.90 b    | 76.01     |
| CV = 13.71%                           | Average                    | 62.87     | 78.07           | 63.09      | (+)       |
| The diameter of blooming flowers (cm) | Control                    | 5.14 bcd  | 4.09 g          | 4.85 cde   | 4.69      |
|                                       | Shading net 30% (S)        | 5.26 bc   | 4.78 de         | 4.99 bcde  | 5.02      |
|                                       | Misting system (M)         | 5.38 b    | 4.27 fg         | 5.42 b     | 5.02      |
|                                       | S and M                    | 6.14 a    | 4.59 ef         | 4.99 bcde  | 5.24      |
| CV = 4.74%                            | Average                    | 5.49      | 4.43            | 5.06       | (+)       |
| The length of pedicels (cm)           | Control                    | 17.72     | 19.90           | 19.37      | 19.00 b   |
|                                       | Shading net 30% (S)        | 17.37     | 19.61           | 19.61      | 18.39 b   |
|                                       | Misting system (M)         | 17.55     | 19.72           | 21.62      | 19.64 b   |
|                                       | S and M                    | 19.40     | 20.55           | 24.56      | 21.57 a   |
| CV = 7.46                             | Average                    | 18.01 c   | 19.59 b         | 21.29 a    | (-)       |
| Chroma a                              | Control                    | 3.17 d    | -2.68 e         | 31.08 ab   | 10.52     |
|                                       | Shading net 30% (S)        | 3.13 d    | -4.46 e         | 34.92 a    | 11.13     |
|                                       | Misting system (M)         | 3.33 d    | -3.27 e         | 30.29 b    | 10.13     |
|                                       | S and M                    | 2.91 d    | -4.90 e         | 25.18 c    | 7.72      |
| CV = 23.67%                           | Average                    | 3.13      | -3.86           | 30.36      | (+)       |
| Chroma b                              | Control                    | 2.57      | 75.70           | 22.21      | 33.49 a   |
|                                       | Shading net 30% (S)        | 2.51      | 76.31           | 22.07      | 33.62 a   |
|                                       | Misting system (M)         | 1.47      | 75.72           | 22.05      | 33.07 a   |
|                                       | S and M                    | 3.47      | 76.18           | 21.95      | 33.86 a   |
| CV=5.62                               | Average                    | 2.50c     | 75.98 a         | 22.06 b    | (-)       |
| Harvesting time (day)                 | Control                    | 104 c     | 106 b           | 108 a      | 106.00    |
|                                       | Shading net 30% (S)        | 106 b     | 106 b           | 108 a      | 106.67    |
|                                       | Misting system (M)         | 104 c     | 106 b           | 106 b      | 105.33    |
|                                       | S and M                    | 106 b     | 106 b           | 108 a      | 106.67    |
| CV = 0.00%                            | Average                    | 105       | 106             | 107.5      | (+)       |

Note: CV = coefficient of variations.

Means followed the same letter at the same column are not significantly different based on Duncan Multiple Range Test,  $p = 0.05$ .

Sign (-) showed there was no interaction and sign (+) showed there was interaction between the environmental modification and varieties.

length of pedicels. The use of shading net delayed the harvesting time for two days on Yastayuki, while the misting system accelerated the harvesting time two days earlier in Socakawani.

The measurement of the flower color using a chromameter showed that there was a decrease in the value of a value in Socakawani flowers with the combination of shading

net and misting system. The a value is identical to red color, containing the anthocyanin (Wang et al. 2001). This showed that the red color has faded in Socakawani flower. However, there was no change in the value of b of all varieties in all environmental modification types. The b value is identical to yellowness color containing the carotenoid (Kishimoto et al. 2007).

### Correlation Analysis Between Microclimate and Morphological Quality of Chrysanthemum

The temperature was positively significantly correlated with light intensity (0.99) and negatively correlated with relative humidity (-0.97). The temperature and light intensity were positively correlated with stomata opening width (0.62 and 0.65) and leaf temperature (0.92) and negatively correlated with transpiration (0.51 and 0.52). As a result, the temperature and light intensity decrease due to environmental modification was negatively correlated with the length of the internode (-0.63) and positively correlated with the number of flower buds formed (0.71 and 0.69). The number of flower buds formed was negatively correlated with the percentage of the number of blooming flowers (-0.77).

## DISCUSSION

### Application of Shading Net on Screen House

The shading net reduced the temperature and light intensity to 28.3 °C and 16,952 Lux, respectively. However, it increased humidity to 77.9%. It reduced the leaf surface temperature, width of stomata pore aperture, and transpiration. Based on Janka et al. (2015), the reduction of the width of stomata pore aperture indicated a decrease in stomata conductance which results in the lack of CO<sub>2</sub> entering the leaves for photosynthesis. This was shown by the reduction in total dry weight of plants in all varieties in shading net.

The light intensity and temperature reduction has also reduced the allocation of dry weight to the stem. The reduction of dry weight of the stem was due to the reduction of stem diameter followed by the increase in plant height and internodes length at 70 DAP or two weeks after the treatments. According to Dierck et al. (2017), the increase in internodes length was due to the light quality variation, namely an increase in the proportion of far red light to red light (Rajapakse and Kelly 1992). Another consequence was a decrease in the number of flower buds at 70 DAP compared to control for all varieties. According to Yuan et al. (2018) the shading net increased the auxin content in the flower. Thus, it inhibited the growth of axillary buds and flower bud outgrowth. After 70 DAP, the apical flower buds and flower buds located 20 cm from the top were removed. The increasing of internodes length affected the number of flower buds that could be seen at 84 DAP in all varieties.

Furthermore, the number of flower bud growths from the varieties with secondary branching type (Yastayuki and Socakawani), increased as well as the number of blooming flower characteristics. Thus, an alteration of the allocation of dry weight from stems to flowers to

increase the blooming rate might be occurred (Misra et al. 2013). It could be proved by calculating the mass ratio of trait of interest to the control. The slower the allocation of dry matter, the longer the harvesting time of Yastayuki. The growth rate of flower buds of Arosuka Pelangi was lower than control at 70 DAP until harvesting time. However, a decrease in the number of flower buds significantly increased the number of flowers and the diameter of the flowers. While the assimilate allocation had been translocated to the flowers, a decrease in total number of flower buds was also reducing the competition among flower buds. Consequently, it increased the number of blooming flowers and blooming flower diameter which had the same harvesting time (Carvalho et al. 2006; Kozłowska et al. 2011). The flower color had determined the quality of chrysanthemums. The temperature and light intensity reduction due to shading net did not affect the biosynthesis of carotenoids or anthocyanins.

### Application of Misting System in Screen House

The misting system reduced the temperature and light intensity to 28.1 °C and 18,083 Lux, respectively. It increased the humidity to 78.7%, but reduced the leaf surface temperature. However, it had no effect on the transpiration, width of stomata pore aperture, and stomata density. The misting system did not change the accumulation of dry matter. However, the reduction of light intensity has increased internodes length since 70 DAP.

The removal of flower buds located 20 cm from the plant tip after 70 DAP affected the number of flower buds at 84 DAP. The total number of flower buds which decreased at 84 DAP increased the number of blooming flowers and diameter of the blooming flowers in all varieties. The harvesting time of Socakawani was two days earlier than control. Therefore, there was no change of flower mass ratio compared to the control. There was no alteration of yellow color in Arosuka Pelangi and red color in Socakawani flowers. It shows that reduction of temperature and light intensity in misting system did not affect the biosynthesis of carotenoids or anthocyanins.

### Combination of Shading Net and Misting System in the Screen House

The combination of shading net and misting system reduced the temperatures to 27.14 °C with a very drastic reduction in light intensity to 11,355 Lux. These

conditions reduced leaf surface temperature, width of stomata pore aperture, and transpiration resulted in the decrease in photosynthesis product in stems and flowers. This result is in accordance with Ozturk et al. (2013) who reported that the light intensity reduction decreased the photosynthesis of chrysanthemum. The reduction of photosynthesis rate was the result of the decrease in CO<sub>2</sub> concentration in leaf due to a reduction in stomatal conductivity in low light intensity (Han et al. 2017). The low light intensity changed the plant morphology, such as increasing of internodes length, accompanied by a decreasing of stem diameter from 70 DAP.

Low light intensity caused mechanisms of shade avoidance in chrysanthemums. The shading net increased the proportion of red and far red light which stimulates the formation of auxin in the apical meristem (Demotes-Mainard et al. 2016). In addition, it increased internode length and inhibited the axillary buds (Dierck et al. 2017). Furthermore, Yuan et al. (2018) showed that the shading which decreased the ratio of red and far red light, would inhibit the growth of flower buds, depending on the location in the stem. The treatment to keep the number of flower buds located 20 cm from the tip decreased the number of flower buds at 84 DAP. It was caused by the internode extension since 70 DAP.

Furthermore, the combination of shading net and misting system reduced the number of flower buds in all varieties. Huld and Andersson (1997) reported that as the light intensity was low, the lower shaded leaves would act as sinks. Thus, they would have a competition with flower formation. It is caused by the reduction of assimilate allocation to the flower buds. The availability of assimilates for flower development would be inhibited when the light intensity less than 12,383 Lux (Carvalho and Heuvelink 2003). These conditions would decrease the number of blooming flowers, but increase the diameter of blooming flowers.

The rate of dry matter allocation to increase the flower diameter affected the harvesting time two days longer than control in Yastayuki. In the meantime, the decrease in the number of flower buds increased the percentage of the number of blooming flowers. It did not affect flower diameter and harvesting time in Arosuka Pelangi and Socakawani. The combination of shading net and misting system with the temperature of 27.14 °C and light intensity of 11,355 Lux actually reduced the anthocyanin content of flower petals compared to control. It has been known that light intensity is needed for anthocyanin biosynthesis in chrysanthemum flowers at least around 10,000 Lux (Hong et al. 2015; Hong et al. 2016) and maximum of about 60,000 Lux (Kim et al. 2004). Increasing day and night temperatures of 35/20 °C (Huh et al. 2008) or average temperatures from 25 to 30 °C (Nozaki and

Fukai 2008) reduced the anthocyanin biosynthesis in chrysanthemums. Kim et al. (2004) reported that the fading of chrysanthemum red flower had been reduced by increasing the average temperature up to 32 °C.

## CONCLUSION

The environmental modification which is suitable in the medium upland elevation is either the addition of shading net or misting system. These additions can increase the number of blooming flowers and flower diameter through a process of decreasing the growth of the flower buds. When the number of flower buds decreased, the competition between flower buds was reduced. Consequently, there will be more blooming flowers with large diameter. We recommended the addition of a shading net on screen house was the most suitable screen house environmental modification for increasing chrysanthemum quality at the medium upland elevation.

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Table 6. Correlation analysis between microclimate and external quality traits of chrysanthemum in screen house environmental modification.

|    | 1      | 2      | 3      | 4     | 5      | 6      | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14     | 15    | 16     | 17    | 18    | 19   | 20    | 21    | 22   |
|----|--------|--------|--------|-------|--------|--------|-------|-------|-------|-------|-------|-------|-------|--------|-------|--------|-------|-------|------|-------|-------|------|
| 1  | 1.00   |        |        |       |        |        |       |       |       |       |       |       |       |        |       |        |       |       |      |       |       |      |
| 2  | 0.99*  | 1.00   |        |       |        |        |       |       |       |       |       |       |       |        |       |        |       |       |      |       |       |      |
| 3  | -0.97* | -0.97* | 1.00   |       |        |        |       |       |       |       |       |       |       |        |       |        |       |       |      |       |       |      |
| 4  | 0.62*  | 0.65*  | -0.58* | 1.00  |        |        |       |       |       |       |       |       |       |        |       |        |       |       |      |       |       |      |
| 5  | 0.41   | 0.42   | -0.44  | 0.03  | 1.00   |        |       |       |       |       |       |       |       |        |       |        |       |       |      |       |       |      |
| 6  | 0.92*  | 0.92*  | -0.97* | 0.54* | 0.44   | 1.00   |       |       |       |       |       |       |       |        |       |        |       |       |      |       |       |      |
| 7  | -0.51  | -0.52* | 0.48   | -0.40 | -0.23  | -0.44  | 1.00  |       |       |       |       |       |       |        |       |        |       |       |      |       |       |      |
| 8  | -0.01  | -0.03  | 0.05   | -0.14 | -0.31  | 0.03   | 0.37  | 1.00  |       |       |       |       |       |        |       |        |       |       |      |       |       |      |
| 9  | 0.23   | 0.26   | -0.23  | 0.23  | -0.39  | 0.28   | 0.14  | 0.62* | 1.00  |       |       |       |       |        |       |        |       |       |      |       |       |      |
| 10 | 0.32   | 0.33   | -0.39  | 0.24  | -0.33  | 0.44   | 0.07  | 0.52* | 0.80* | 1.00  |       |       |       |        |       |        |       |       |      |       |       |      |
| 11 | 0.30   | 0.30   | -0.43  | 0.22  | 0.09   | 0.41   | -0.12 | -0.24 | -0.05 | 0.51* | 1.00  |       |       |        |       |        |       |       |      |       |       |      |
| 12 | -0.43  | -0.43  | 0.47   | -0.18 | -0.51* | -0.44  | 0.55* | 0.54* | 0.43  | 0.32  | -0.21 | 1.00  |       |        |       |        |       |       |      |       |       |      |
| 13 | 0.10   | 0.11   | -0.10  | 0.12  | -0.47  | 0.16   | 0.21  | 0.69* | 0.93* | 0.77* | -0.07 | 0.55* | 1.00  |        |       |        |       |       |      |       |       |      |
| 14 | -0.63* | -0.63* | 0.70*  | -0.22 | -0.40  | -0.73* | 0.49  | 0.22  | 0.00  | -0.17 | -0.35 | 0.70* | 0.06  | 1.00   |       |        |       |       |      |       |       |      |
| 15 | 0.71*  | 0.69*  | -0.76* | 0.40  | 0.24   | 0.75   | -0.25 | 0.04  | 0.13  | 0.53  | 0.71* | -0.34 | 0.04  | -0.56* | 1.00  |        |       |       |      |       |       |      |
| 16 | -0.34  | -0.34  | 0.34   | -0.16 | -0.25  | -0.33  | 0.30  | -0.03 | -0.22 | -0.02 | 0.26  | 0.06  | -0.29 | 0.31   | 0.02  | 1.00   |       |       |      |       |       |      |
| 17 | -0.08  | -0.04  | -0.08  | -0.12 | 0.10   | 0.16   | -0.12 | -0.11 | 0.04  | 0.20  | 0.34  | -0.17 | 0.02  | -0.31  | 0.09  | 0.06   | 1.00  |       |      |       |       |      |
| 18 | -0.63* | -0.58* | 0.59*  | -0.38 | -0.14  | -0.52* | 0.14  | -0.08 | -0.09 | -0.31 | -0.37 | 0.19  | 0.00  | 0.27   | -0.77 | 0.00   | 0.55* | 1.00  |      |       |       |      |
| 19 | -0.31  | -0.30  | 0.40   | -0.08 | -0.39  | -0.37  | 0.45  | 0.59* | 0.54* | 0.22  | -0.47 | 0.72* | 0.63* | 0.63*  | -0.45 | -0.04  | -0.35 | 0.18  | 1.00 |       |       |      |
| 20 | -0.13  | -0.17  | 0.15   | -0.05 | -0.48  | -0.07  | 0.37  | 0.68* | 0.55* | 0.56* | -0.03 | 0.53* | 0.68* | 0.22   | 0.06  | -0.16  | -0.13 | -0.09 | 0.49 | 1.00  |       |      |
| 21 | 0.05   | 0.05   | -0.07  | 0.13  | -0.54* | 0.10   | 0.36  | 0.64* | 0.69* | 0.83* | 0.31  | 0.52* | 0.71* | 0.19   | 0.32  | 0.23   | -0.09 | -0.32 | 0.37 | 0.65* | 1.00  |      |
| 22 | 0.00   | 0.00   | 0.00   | -0.06 | 0.08   | 0.05   | -0.22 | -0.05 | 0.13  | -0.17 | -0.47 | -0.06 | 0.23  | -0.25  | -0.37 | -0.76* | 0.14  | 0.41  | 0.15 | 0.12  | -0.44 | 1.00 |

Note: (1) air temperature, (2) light intensity, (3) relative humidity, (4) width of stomata pore aperture, (5) stomata density, (6) leaf surface temperature, (7) transpiration, (8) leaf dry weight, (9) stem dry weight, (10) flower dry weight, (11) flower mass ratio, (12) plant height, (13) stem diameter, (14) internodes, (15) total flowers, (16) diameter of blooming flowers, (17) number of blooming flowers, (18) percentage of the number of blooming flowers, (19) pedicel length, (20) harvesting time, (21) chroma a, (22) chroma b.

The sign (\*) showed that the correlation is significant at the 0.05 level (2-tailed).