Effect of Light Intensity, Plant Density, and Flower Bud Removal on the Flower Size and Number in Cut Chrysanthemum

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Abstract

Flower size and number of flowers per plant are important external quality aspects in cut chrysanthemum. The present work is conducted in a glasshouse and aims at investigating how these quality aspects can be predicted. To evaluate individual flower size, different levels of supplementary lighting (control and assimilation light), plant density (32, 48 and 64 plants m^{-2}) and lateral flower bud removal (leaving 1 flower, 4 flowers and control) were applied. To analyse the effect of assimilate supply on number of flowers per plant, three light intensities (no shade control, 65% light, and 45% light) where combined with three plant densities (32, 64, and 80 plants m^{-2}).

Individual flower size was negatively influenced by competition for assimilates in the treatments with a fixed number of flowers per plant (1 or 4 flowers). In such treatments, plants grown under no supplementary assimilation light, higher plant density, or with higher number of flowers per plant resulted in significantly lower individual flower dry mass and area. However, when no lateral flower buds were removed (control), higher assimilate supply resulted in more flowers rather than in larger flowers. Number of flowers per plant (including flower buds) showed a positive linear increase with total dry mass per plant. The combination of 32 plants m^{-2} and no shade resulted in the highest number of flowers per plant (33 flowers) in contrast with 80 plants m^{-2} and 45% light intensity (only 9 flowers).

INTRODUCTION

Chrysanthemum is world-wide an important greenhouse crop, both as cut flower and as pot plant, and it is one of the most intensive and controlled crop production systems in horticulture (Machin, 1996). Prices of cut flowers are often determined on the basis of visible quality aspects (external quality) (Vonk Noordegraaf and Welles, 1995) and growers have been facing strong pressure to supply regular quality during the whole year (Langton et al., 1999).

External quality of cut chrysanthemum is usually evaluated in terms of stem and leaf morphology and flower characteristics. Each external quality aspect is influenced by several growing conditions that interact with each other (Carvalho and Heuvelink, 2001). Taking into account the complexity of such a system, the development of a mechanistic model as part of a decision support tool to control chrysanthemum external quality throughout the year, is very important (Carvalho and Heuvelink, 2001). However, there are still few crop models in ornamentals and these are mainly focused on growth and development rather than on product quality (Gary et al., 1998).

It has been long since it was reported that treatments which produced heavier plants showed higher flower weight ratios (Cockshull; 1967). However, it remains unclear whether this results from an increased individual flower size, a higher number of flowers per plant, or from both aspects. In the present work, the hypothesis that higher assimilate supply (higher light intensity and lower plant density) has a positive effect on both individual flower size and number of flowers per plant is tested. Also, the effect of decreasing the competition for assimilates, by removing lateral flower buds, on individual flower size is quantified. The final aim of this study is to predict size and number of

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flowers per plant in cut chrysanthemum, as these aspects are of utmost importance for a high quality plant.

MATERIALS AND METHODS

General Procedures

Three experiments were carried out in 12.8 m × 12.0 m compartments, being part of a multispan Venlo-type glasshouse (Wageningen University, The Netherlands, lat. 52°N). Block-rooted cuttings of *Chrysanthemum* 'Reagan Improved' were obtained from a commercial propagator and planted in soil beds on the dates indicated in Table 1. Plants were grown under long-day conditions during the first 3 weeks, followed by a short-day treatment until the moment of harvest. In the autumn experiments (Exp. 1 and 2), the photoperiod was ensured by supplementary lighting (Table 1). In Exp. 1, light from either incandescent lamps (control, 6.3 μmol m^{-2} s^{-1} PAR) or assimilation lamps (high pressure sodium HPS, Philips SON-T Agro, 42.3 μmol m^{-2} s^{-1} PAR) was applied. In Exp. 2, only HPS lamps were used. Lamps were continuously on during the photoperiod in both autumn experiments. In the summer experiment (Exp. 3), plants were grown under natural light conditions during the long-day treatment and short day conditions were achieved by closing the blackout screen for 13 hours each day (Table 1). Every 5-min, climatic conditions (outside global radiation, greenhouse temperature, and CO_2 concentration) were automatically recorded by a commercial computer system (Hoogendoorn, Vlaardingen, The Netherlands). Average values are presented in Table 1.

As commonly practiced in commercial cut chrysanthemum production, the terminal flower bud was pinched in all treatments as soon as it was detached from the other crown buds (<5mm), except for the terminal flower treatment ($1F_T$). Plants were harvested when the first row of disc florets was in anthesis in at least three inflorescences per plant. Harvest dates were, therefore, spread over approximately 1 week (Table 1) since flower development rate differed slightly among treatments. Dry mass of the flowers (ventilated oven, 105°C for at least 15h), individual flower area (LI-COR Model 3100 Area Meter, USA), and number of flowers and flower buds (>5mm) were determined at harvest (Exp. 1 and 2). In Exp. 3, the flowers and flower buds were counted and total dry mass per plant (excluding roots) was determined. Measurements were done on 5 (Exp. 3) or 6 (Exp. 1 and 2) plants per experimental plot. Each experimental plot consisted of 54 plants and the harvested plants were chosen as being representatives of the plot and leaving a minimum of two border rows between different treatments. A linear regression analysis and an analysis of variance were conducted. Treatment effects were tested using an *F*-test at 5 % probability level, except for the effect of supplementary light (Exp. 1). This effect was tested at $P = 0.10$ because of the very low residual degrees of freedom (d.f. = 1). Mean separation was done using Student's *t*-test at 5% probability level.

Individual Flower Size (Exp. 1 and 2)

Two experiments were carried out to study the individual flower size. In Exp. 1, ten treatments were conducted resulting from two levels of supplementary lighting (control and HPS lamps), combined with five levels of lateral flower bud removal ($1F_T$: only the terminal flower left on the plant; $1F_1$: only the apical flower, at node 1, left on the plant; $4F_{1-4}$: four apical flowers, at node 1 through 4, left on the plant; $F4_{5-8}$: four apical flowers, at node 5 through 8, left on the plant; C: control, only the terminal flower removed). Monoflower treatments ($1F_T$ and $1F_1$) were obtained by removing regularly the lateral shoots, as soon as they became visible. In the $4F_{1-4}$ and $4F_{5-8}$ plants, the lateral shoots were retained and only the extra lateral flower buds were pruned when visible. The control plants were allowed to develop flowers without interference (except the removal of the terminal bud). Only the four apical lateral flowers, at node 1 through 4, were used to determine the average flower dry mass and area, because the other flowers were still not fully opened at harvest. Plants were grown at a density of 64 plants m^{-2}.

In Exp. 2, three plant densities (32, 48, and 64 plants m^{-2}) were combined with two levels of flower bud removal ($1F_T$ and C, as described in Exp. 1).

The experimental set-up was a split-plot design with light intensity (Exp. 1) or plant density (Exp. 2) as the main plots (with 2 replicates) and lateral flower bud removal in the sub-plots.

Number of Flowers Per Plant (Exp. 3)

In Exp. 3, nine treatments were included. Three light intensities (no shade control, 65% light, and 45% light) were applied as the main factor, each consisting of two parallel soil beds next to each other (with 3 replicates). Within each light level, three plant densities (32, 64, and 80 plants m^{-2}) were randomised (split-plot design). Shade was obtained by installing a white plastic net of two different meshes on the top (1.5m height from the ground) and sides of the crop.

RESULTS

Individual Flower Size

A significant interaction ($P<0.001$) between light intensity and flower bud removal was observed for individual flower dry mass (Fig. 1A). Plants grown with supplementary assimilation light (HPS), compared to the control, had significantly heavier flowers, except for the control treatment (no lateral flower bud removal). Monoflower treatments ($1F_T$ and $1F_1$) had the highest flower dry mass, followed by the average of the 4 flowers from $4F_{1-4}$ and $4F_{5-8}$ treatments. For the control treatment, the average dry mass of the first four apical flowers (at node 1 through 4) was the same as for the F4 treatments at no supplementary assimilation light, whereas significantly lower under assimilation light (Fig. 1A). Individual flower area also showed significant interaction ($P=0.081$) between light intensity and flower bud removal. Similar results as for flower dry mass were observed (Fig. 1B).

Flower position on the stem had no significant influence on flower dry mass and area when comparing F4 treatments. However, the top monoflower ($1F_T$) under supplementary assimilation light was bigger and heavier than the first lateral monoflower ($1F_1$) (Fig. 1).

In Exp. 2, a significant interaction between plant density and flower bud removal was found for both individual flower dry mass ($P=0.004$) and individual flower area ($P=0.008$) (Fig. 2). At the three studied plant densities, flower dry mass and area was significantly larger in the monoflower plants than in the control treatment when looking at the average of the first four apical flowers. However, decreasing plant density significantly increased flower's dry mass and area of the $1F_T$, whereas no effect was observed in the control plants (Fig. 2).

Number of Flowers Per Plant

A positive linear relation was observed between total number of flowers (including flower buds) and total dry mass production per plant when combining three light intensities with three plant densities (Fig. 3). Plants grown under no shade (control) and at the lowest plant density (32 plants m^{-2}) showed the highest number of flowers (33 flowers per plant). Similarly, the opposite treatment combination, i.e. the lowest light intensity (45% light) combined with the highest plant density (80 plants m^{-2}), resulted in the lowest number of flowers (9 flowers per plant).

DISCUSSION

Individual flower size was not affected by assimilate supply in the control treatment (Fig. 1 and Fig. 2). However, treatments with a fixed number of flowers per plant proved that flower size has potential to increase at higher assimilate supply (e.g,. assimilation light, lower plant density, and less flowers per plant) (Fig. 1 and Fig. 2). This agrees with earlier findings where a higher individual flower dry mass was observed in

pot chrysanthemum as a result of axillary flowers removal (Cockshull, 1982). The lack of effect of higher assimilate supply on flower size, observed in the control plants, is possibly due to the increased number of flowers per plant. This increase in number of flowers is consistent with previous studies (Eng et al., 1985; Andersson, 1990; Heuvelink et al., 1998). Therefore, it seems that the plant invests the additional assimilates in increasing the number of flowers (Fig. 3), rather than in increasing their size (Fig. 1 and 2). This did not occur in treatments with a fixed number of flowers per plant, because flower buds were constantly removed.

From this work, it can be concluded that to model individual flower size of spray type cultivars, light intensity and plant density are not important inputs to the model. However, to predict number of flowers per plant, a photosynthesis-driven model could be used to estimate total dry mass per plant (Heuvelink et al., 2001) and from that, number of flowers per plant can be predicted (Fig. 3).

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Tables

Table 1. Planting and harvest dates, length of photoperiod and climatic data for three experiments in *Chrysanthemum* 'Reagan Improved'. Radiation, greenhouse temperature and CO_2 concentration were averaged over the whole growing period.

Exp.	Planting; Harvest	Photoperiod (h)	Outside global radiation (mol $m^{-2}d^{-1}$)	Incident PAR [z] (mol $m^{-2}d^{-1}$)	Temperature (°C)	CO_2 (µmol mol^{-1})
1 and 2	30 Sept. 1999; 14-21 Dec. 1999	19 [X] (0500; 2400) 10 [Y] (0800; 1800)	18.4	4.1 (Control) 5.8 (HPS)	19.0	578 (Exp. 1) 432 (Exp. 2)
3	8 June 2000; 23-28 Aug. 2000	17.5 [X] (0500; 2230) 11 [Y] (0800; 1900)	78.1	17.0	22.0	349

[X] under long-day treatment
[Y] under short-day treatment
[Z] Based on measured glasshouse transmissivity of 49% and supplementary light included (Control: 0.28 mol $m^{-2}d^{-1}$ and HPS: 1.93 mol $m^{-2}d^{-1}$)

Figures

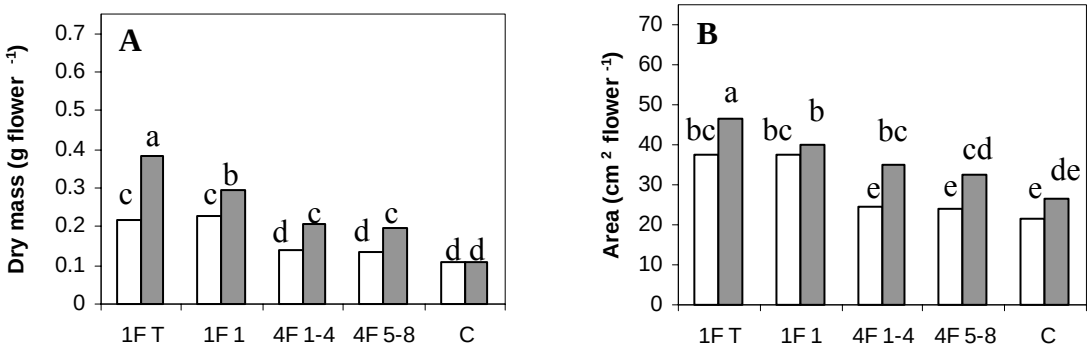

Fig. 1. Individual flower dry mass (A) and individual flower area (B) as a function of flower bud removal and supplementary light (white bars: control; grey bars: assimilation light) at final harvest of Chrysanthemum 'Reagan Improved' (Exp. 1). Different letters indicate significant differences between treatments (LSD = 0.048 (A); LSD = 6.27 (B)).

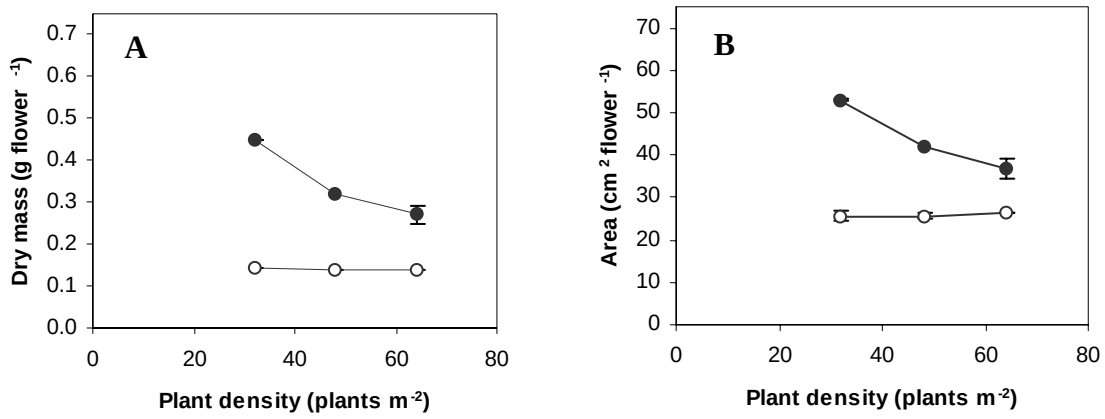

Fig. 2. Individual flower dry mass (A) and individual flower area (B) as a function of number of flowers per plant (=:1FT monoflower; o: control) and plant density (32, 48 and 64 plants m-2) at final harvest of Chrysanthemum "Reagan Improved" (Exp. 2). Vertical bars indicate standard error of mean when larger than symbols (n=2). Number of flowers per plant, in the control treatment, was 22.4 ± 3.4 (32 plants m^{-2}), 17.2 ± 0.2 (48 plants m^{-2}) and 11.3 ± 1.3 (64 plants m^{-2}).

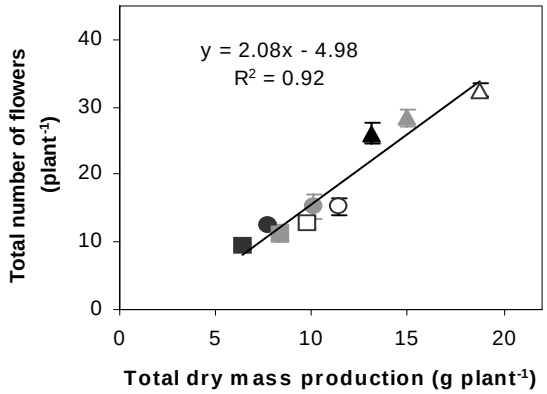

Fig. 3. Number of flowers per plant (including buds) as a function of total dry mass production at final harvest of Chrysanthemum (Exp. 3). Each symbol represents the average from the combination of three light intensity levels (△, ○, □: 100%; ▲, ●, ■: 65% and ▲, ●, ■: 45%) and three plant densities (△, ▲, ▲: 32 plants m^{-2}; ○, ●, ●: 64 plants m^{-2} and □, ■, ■: 80 plants m^{-2}). Vertical bars indicate standard error of mean when larger than symbols (n=3).