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Influence of long days on the production of cut chrysanthemum cultivars

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ABSTRACT

Chrysanthemum is one of the most widely marketed cut flower in the world. For this flower cultivation, long days to induce vegetative growth are required, until the plant reaches the necessary size for commercial flowering. The aim of this study was to evaluate the influence of the number of long days on the production of floral stems of five cut chrysanthemum cultivars. The experiment was evaluated in a randomized block design with split plots, with two factors and three replicates. Considering the number of long days (21, 28, 35, 42 and 49) the plots, and sub-plots the cut chrysanthemum cultivars (Calábria, Dragon, Sheena, Apricot Repin and Rebasco). We noticed significant differences for most of morphological traits for number of long days, and for interaction of cultivar x number of long days. Dragon, Apricot Repin and Calábria were the cultivars which stood out producing greater vigor of stems and better agronomic quality. Sheena and Rebasco cultivars showed the lowest performance among the evaluated cultivars, though. The cut chrysanthemum cultivars showed agronomic performance which allows a reduction in the number of long days of exposure, from 35-45 days usually practiced, to 21-28 days, reducing the time required for commercialization.

Keywords: *Chrysanthemum morifolium*, genotype, flowering, cultivation time, photoperiod.

RESUMO

Influência de dias longos na produção de cultivares de crisântemo de corte

O crisântemo é uma das espécies mais comercializadas como flor de corte. No seu cultivo utilizam-se dias longos para induzir o crescimento vegetativo, de forma que a planta se mantenha neste estágio durante período suficiente para a floração comercial. Assim, o objetivo deste trabalho foi estudar a influência do número de dias longos na produção de hastes florais de cinco cultivares de crisântemo de corte. O experimento foi realizado no delineamento em blocos casualizados no esquema de parcelas subdivididas com dois fatores e três repetições. Sendo os números de dias longos (21, 28, 35, 42 e 49) as parcelas e as cultivares de crisântemo de corte (Calábria, Dragon, Rebasco, Sheena e Apricot Repin) as sub-parcelas. Houve diferença significativa para a maioria das características em função do número de dias longos, da cultivar e da interação cultivar x número de dias longos. Dragon, Apricot Repin e Calábria foram as cultivares que se destacaram produzindo hastes com maior vigor e melhor qualidade agronômica. Entretanto, Sheena e Rebasco tiveram um desempenho abaixo da média das cultivares. As cultivares de crisântemo de corte apresentaram desempenho agronômico que permitiu a diminuição do número de dias longos de exposição, de 35 a 45 dias normalmente praticada, para 21 a 28 dias, reduzindo o tempo de cultivo.

Palavras-chave: *Chrysanthemum morifolium*, genótipo, florescimento, tempo de cultivo, fotoperíodo.

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The production of flowers and ornamental plants has been continuously growing due to improvement in market structure, growth in population's and producers' purchasing power, diversification of species, diffusion of new production technologies and professionalization of the members of the Brazilian production chain. The market totaled 5.22 billion Reais (US$ 2.21 billion) in 2013 (Junqueira & Peetz, 2014).

Chrysanthemum is the second main species of cut flower produced in Brazil (15%), second only to roses, which represent 30% of the market. Other species like lisianthus (12%), lily (7%) and gerbera (6%) complement the main cut flowers in the national market. Chrysanthemum also stands out as flower pots, considering the main species: orchids (14%), lily (7.5%), chrysanthemum (7%), kalanchoe (6.4%), violet (6%) and bromeliad (4.5%) (Junqueira & Peetz, 2013). It is one of the most expressive flowers in the market, due to its great diversity in relation to size, color, shape and longevity of inflorescences, early production and accuracy of photoperiod response (Barbosa, 2003; Mainardi *et al.*, 2004; Brackmann *et al.*, 2005).

The chrysanthemum is classified as a short-day plant for flowering, with critical photoperiod of 13 hours (Gruszynski, 2001). When the length of the day is longer than 13 hours, we observe vegetative growth with differentiation in nodes, internodes and leaves, resulting in higher plants and higher fresh mass of the plant (Barbosa, 2003; Barbosa *et al.*, 2005). The combination of the number of long days and the number of short days is fundamental so that the plant can develop until reaching a minimum height for the commercialization, allowing production of flowers per clusters and greater

number of inflorescences per stem.

In floriculture, quality is defined as the set of attributes which makes the product saleable. Consumer acceptability of these products is evaluated by visual characteristics, such as size and shape, health conditions, turgor and maturity (Magalhães *et al.*, 2005). Factors, such as, number of plants, genetics and environmental, are determinant for the production of floral stems with quality. This quality can be evaluated using the length, stiffness and healthy floral stem, diameter and degree of inflorescence opening (Farias *et al.*, 2009). The Instituto Brasileiro de Floricultura (Brazilian Institute of Floriculture) (IBRAFLOR) follows the quality criteria proposed by the Departamento de Qualidade (Quality Department) at Veiling Holambra Cooperative. The classification criterion of chrysanthemum is used to separate the products according to the standard and quality. The standard are measurable characteristics of the product containing 95% uniformity, such as the stem length (which ranges from 45 to 80 cm), bunch weight (1.1 or 1.3 kg with 5% tolerance), point of maturation and soft stems (stems that have a slope when held by the end of the base, acceptable up to 30 degrees of slope). The quality category (A1 or A2) is defined as absence of defects and characterizes the lot quality. The quality should be established according to tolerance limits for severe damage (rust damage, botrytis and pests, mechanical damage, yellow and/or dry leaves and lack of total leaves) and minor defects (burning by phytotoxicity and chemical residue) (Veiling Holambra, 2017). According to Barbosa (2003) in order to be accepted for marketing, floral chrysanthemum stems have to present a minimum length of 55 cm, measuring the stem base up to the last open inflorescence. It is necessary that the plants remain in cultivation, on average, between 35 and 45 long days.

Little information on the number of long days which is necessary in order to reach high-quality stems can be found, since the use of new cultivars and technologies in this productive sector need to be investigated aiming to increase the stem quality with reduction of production cost. Thus, the aim of this study was to evaluate the number of long days necessary for producing floral stems of five cut chrysanthemum cultivars.

MATERIAL AND METHODS

The experiment was performed during the summer (December to April) in Setor de Floricultura in the Departamento de Fitotecnia at Universidade Federal de Viçosa, Viçosa, Minas Gerais State, Brazil (20°45'35,9"S, 42°51'47,6"W, 640 m altitude), in a greenhouse, arch type, and covered with polyethylene film, 150 µm, closed laterally with 50% shading screen.

The experimental design was randomized blocks, split plot scheme with three replicates. Two factors were used: on the plots the number of long days on which the plants were submitted (21, 28, 35, 42 and 49 days) on the split-plots the cut chrysanthemum cultivars (Calábria, Dragon, Rebasco, Sheena and Apricot Repin). The description of each cultivar is shown in Table 1.

The cuttings were obtained without roots and treated with indole-butyric acid (IBA) 0.1% in powder form. Then, these cuttings were placed for rooting in a nebulization chamber using carbonized rice husk-based substrate. Rooting occurred under long-day conditions (16 hours of light), supplied continuously. The artificial lighting was with 100 w incandescent bulbs, spaced 1 m, arranged at cutting apex height of 0.70 m, which remained on from 22 h to 2 h, for 10 days (Barbosa, 2003). The experiment was carried out in a seedbed with 18.2 m length x 1.0 m width x 0.20 m height, with substrate composed of soil, sand and organic matter in the form of tanned cattle manure, in the ratio of 6:3:1, respectively. To the substrate was added 1 g L^{-1} of the mixture of KCl (60% of K_2O) and simple superphosphate (18% P_2O_5, 16% Ca and 8% S), in the ratio of 1:3, respectively. The chemical analysis of the substrate showed the following mineral composition: pH $CaCl_2$= 6.5; CTC= 16.41; P= 195.7 mg dm^{-3} and V%= 29. The experimental plot was composed of five sub-plots. The sub-plots were composed of plant rows, one of each cultivar, with seven plants per row, using five plants for each evaluation. The spacing between plants and between rows was of 12.5 cm. The transplanting on the sides of the seedbeds, where plants were border rows, was carried out. During the cultivation, plants were fertigated using 1 g L^{-1} Peter's Professional 20-20-20 (N-P-K) fertilizer, every seven days, and 10 L of solution per plot. The plants were staked using agricultural nets to prevent stem bending and quality loss (Barbosa, 2003).

Seedlings were transplanted under long-day condition, with 16 hours of light, using one row of 100 W incandescent bulbs, each 2 m, from 10 p.m. to 2 a.m., installed at 1.5 m above ground level (Barbosa, 2003).

After the long-day period of each treatment (21, 28, 35, 42 and 49 days), the plants were kept under short-day conditions, with 10 h photoperiod, aiming to flowering induction. The short day was established covering the plots, with black plastic canvas, from 5 p.m. to 7 a.m.

Short-day treatment was interrupted on the day of apical bud removal, when the bud showed diameter equal to or higher than 8 mm for all the cultivars of the plot. The apical bud removal aims to produce flowers in bunches, method known as "pinch". After the short day, the plants were kept under natural photoperiod.

Plants were harvested when the floral stems showed 2/3 of open inflorescences, it means, when the first row of ligulas was perpendicular to the floral stem (Barbosa, 2003). The plants in the subplots were cut near the soil and standardized as follows: leaves and inflorescences without visible damage, absence of dirt and residues and taken to the laboratory in order to be evaluated. The following characteristics were evaluated: stem height, measured from the collar of the plant up to the highest inflorescence (SH, cm); stem mass, measured fresh mass of floral stems standardized by the size of 80 cm of length, (SM, g); cycle, expressed

by number of days since seedling transplanting until the stem harvest (cycle, days); leaf area, using a leaf area meter, model LI-COR LI-3100C (LA, cm^2); number of inflorescences, considering open inflorescences and buds greater than 0.5 cm; number of inflorescence, average of number of inflorescences per stem (NI), and stem diameter, diameter of the middle section of the stem (SD, mm).

The obtained data were submitted to the analysis of variance and the averages compared using Tukey test. For each variable and in each period, the overall average of the cultivars was calculated. Then, the regression analysis of the averages was obtained and the model which provided the highest coefficient of determination was used. All the statistical analyses were performed using the software Genes, Software for Experimental Statistics in Genetics (Cruz, 2013).

RESULTS AND DISCUSSION

A significant difference between the number of long days for all traits was observed. We also observed a significant difference among the cultivars for stem height, production cycle and leaf area. The interaction number of long days x cultivar was significant for practically all the evaluated traits, except for inflorescence number and stem diameter. The significance of the interaction between cultivars and number of long days means the differentiated performance of the cultivars in relation to long days on which they were submitted.

Stem height

Different number of long days affected significantly the traits related to the plant growth. The higher the number of long days, the greater the height of the stems, as the linear regression of the average number of days shows, which coefficient of determination was close to one (Figure 1A).

Stem heights of the cultivars Apricot Repin, Dragon and Calábria were higher than the average value and showed similar behavior among them. The cultivars Rebasco and Sheena showed lower height than the overall average for all number of long days. Rebasco was the only cultivar which showed a drop in stem height at 42 and 49 long days. The tallest height was observed in cultivar Apricot Repin, 162 cm, at 49 long days and the lowest height in cultivar Sheena, 72 cm, at 21 long days (Figure 1A).

The cultivars did not differ significantly for stem height, only when cultivated at 21 long days (Figure 1A).

Mello *et al.* (2009), studying the cultivars Calábria and Lameet Bright submitted to the technique of interrupted short days, considering 9 short days, followed by 12 long days and then short days until anthesis, observed 135-cm-height stems for Calábria and 125 cm for Lameet Bright. These values were similar to the ones produced by Calábria in this study, at 42 long days (131 cm). Comparing with the numbers of long days used in this study, the technique of interrupted short days, was similar to the use of 35 and 42 long days, for cultivars above average, which produced from 120 to 140-cm-height stem.

Under 28 long days, the stems showed an average growth rate of approximately 10 cm in relation to 21 long days. Only Rebasco did not show any growth rate, in relation to 21 long days (Figure 1A). For other long-day periods, Apricot Repin, Dragon and Calábria were similar among them and superior to the others, growing an average of 15 cm as the number of long days increased.

Stem mass

We noticed a differentiated behavior

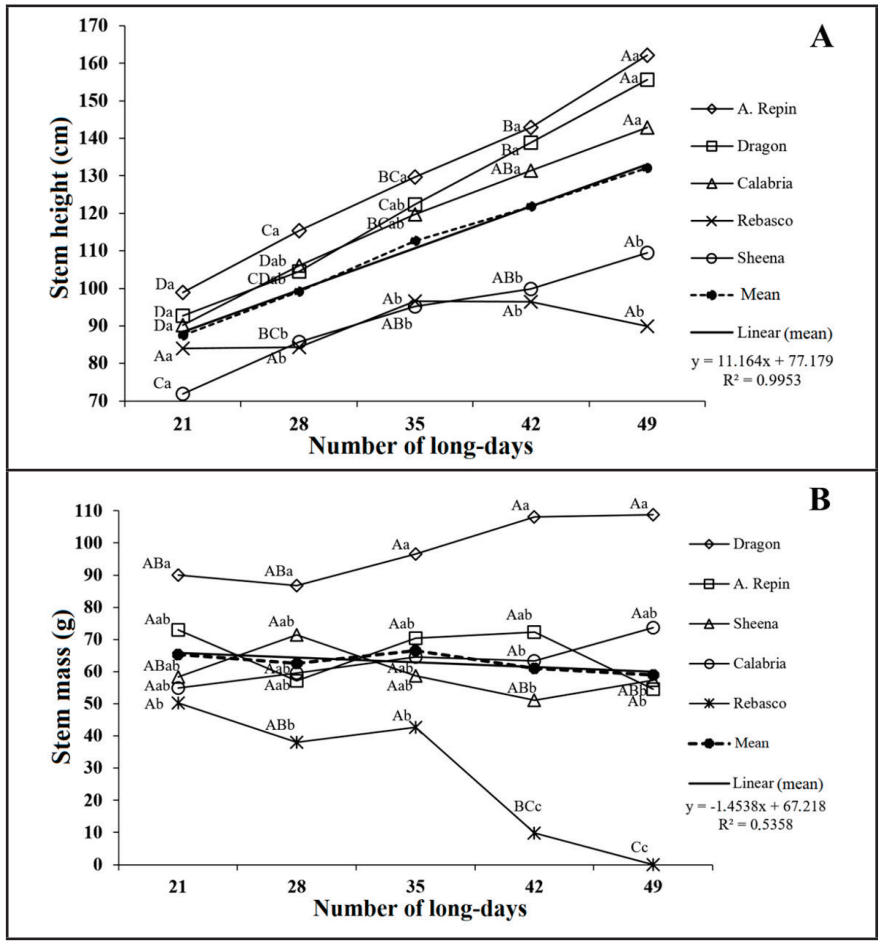


Figure 1. Averages of stem height (A), and stem mass (B) of cut chrysanthemum cultivars grown under different number of long-days. Averages followed by the same capital letters (averages of the cultivar in different periods) and the same lowercase letters within the periods (among cultivars in the period) did not differ statistically among themselves by Tukey test, $p<0.05$. Viçosa, UFV, 2013.

among the cultivars for fresh mass of the 80-cm stem with an increase of number of days under long photoperiod (Figure 1B).

For 21 long-day period, Dragon produced 43% more fresh mass of the 80-cm stem than Rebasco, whereas Calábria, Apricot Repin and Sheena were similar among them, showing values of 55, 73 and 58 g, respectively. Moreover, these three cultivars produced from 51 to 74 g during the five long-day periods. The lower the value of the fresh mass, the bunch needs a greater number of stems for its composition, since a minimum is required to be considered a standard (bunch weight of 1.1 or 1.3 kg with 5% tolerance), which would lead to lower profitability for the producer.

Chica & Correa (2005) evaluated two cut chrysanthemum cultivars Super White, grown under 26 long-day conditions and Super Yellow, under 28 long days. These authors found average values, for fresh mass of the 80-cm stem, of 71 and 61 g per plant, for Super White and Super Yellow, respectively, which were similar to the ones found, in this study, for Sheena, Calábria and Apricot Repin considering the evaluated interval of 21 and 28 long days.

Cycle

Production cycle is a crucial point in cost and, particularly, in production planning, for specific days (mother´s day, Valentine's, Day of the Dead, Christmas), considering that earliness is an important factor in order to reduce costs (Barbosa *et al.*, 2010). The production cycle, number of days from seedling transplanting up to the stem harvest, is directly influenced by the long-day periods in which the plants were submitted.

The different numbers of long days affected significantly the cycle of all cultivars, showing a directly proportional relationship, it means, with an increase in the number of long days, an increase in the cultivar cycle can be noticed; the exception is for cultivar Rebasco which shows a reduction under 35 long days in relation to 28 long days. We verified a reduction from 115 days in production cycle (plants grown under 49 long days) to 85 days (plants grown under 21 long days), which provides the producer great resource and time savings (Figure 2A).

For all the numbers of long days evaluated in this study, the production cycles of Rebasco were greater than the other cultivars, considering that the opposite was observed for cultivar Dragon (Figure 2A). At 21 long days, the cultivar Dragon was the earliest in relation to the other cultivars under 75 days, from transplanting up to stem harvest, the latest cultivar was Rebasco under 95 days. Mainardi *et al.* (2004) observed a differentiated response of the chrysanthemum cultivar Snowdon. When grown under 21 long days, the cycle was of 88 days, similar result was observed for the cultivar Apricot Repin evaluated in this study, and when grown under 28 long days, the cycle was of 100 days.

At 49 long days, the cultivar Rebasco also showed the longest cycle among the cultivars evaluated, 124 days from transplanting up to stem harvest. However, the cultivar Dragon showed a cycle of 100 days. This represents a 24-day earliness, which would be an advantage fact for the producer. Barbosa *et al.* (2000) evaluated the cultivar Yellow Polaris, in two conditions, during the winter under 53 long days and in the summer under 55 long days, values above the ones evaluated in this study. The cycle of the cultivar was of 114 days in the winter, value close to the cultivar Sheena evaluated at 42 long days in this study and 123 days in summer, which was similar to the cycle of cultivar Rebasco evaluated at 49 long days in this study. In different

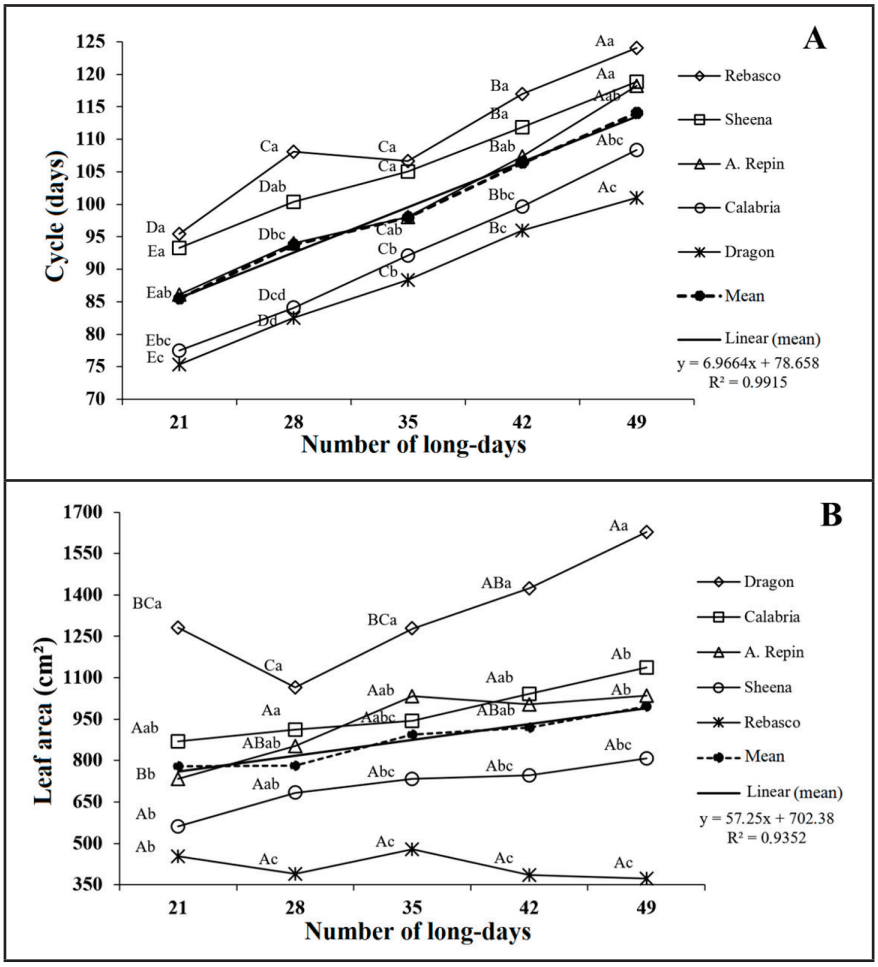


Figure 2. Averages of cycle (A), and leaf area (B) of chrysanthemum cultivars grown under different number of long-days. Averages followed by the same capital letters (averages of the cultivar in different periods) and the same lowercase letters within the periods (among cultivars in the period) did not differ statistically among themselves by Tukey test, $p<0.05$. Viçosa, UFV, 2013.

growing conditions the cycle shows a differentiated behavior, however the behavior of each cultivar in conditions which better represent the producers' necessity has to be observed. The number of long days, provided for the production of chrysanthemum, is always a determining factor for the cycle of any cultivar.

Leaf area

The different numbers of long days influenced the leaf area of the cultivars, showing, in average, a directly proportional relationship among leaf area and number of long days applied. The coefficient of determination of the linear regression of the averages in each period was close to one and the cultivars Dragon, Calábria and Apricot Repin showed values above the average, whereas Rebasco and Sheena kept their values below the average (Figure 2B). Dragon produced greater leaf area during all the long days evaluated and Rebasco showed the lowest performance, and also, a reduction in leaf area from 35 long days on (Figure 2B). At 21 days, Dragon produced leaf area three times greater than the leaf area produced by cultivar Rebasco. Moreover, the greatest variation in leaf area among the cultivars was under 49 long days; Dragon produced 1600 cm^2 and Rebasco produced 350 cm^2, almost five times more. Under 32 long days, Bellé *et al.* (2007) evaluated the cut chrysanthemum cultivar Gompier Chá, at 32 long days, using technique of interrupted short days (32 long days, followed by 9 short days, then 12 long days and afterwards short days until harvest). The leaf area of cultivar Gompier Chá, at 32 long days, was of 998 cm^2. Similar result was found in this study for cultivars Apricot Repin and Calábria, at 35 and 42 long days, respectively. Using the technique of interrupted short days, the authors verified a reduction in leaf area of Gompier Chá (820 cm^2), similar result was found for the cultivar Calábria evaluated at 21 long days, in this study.

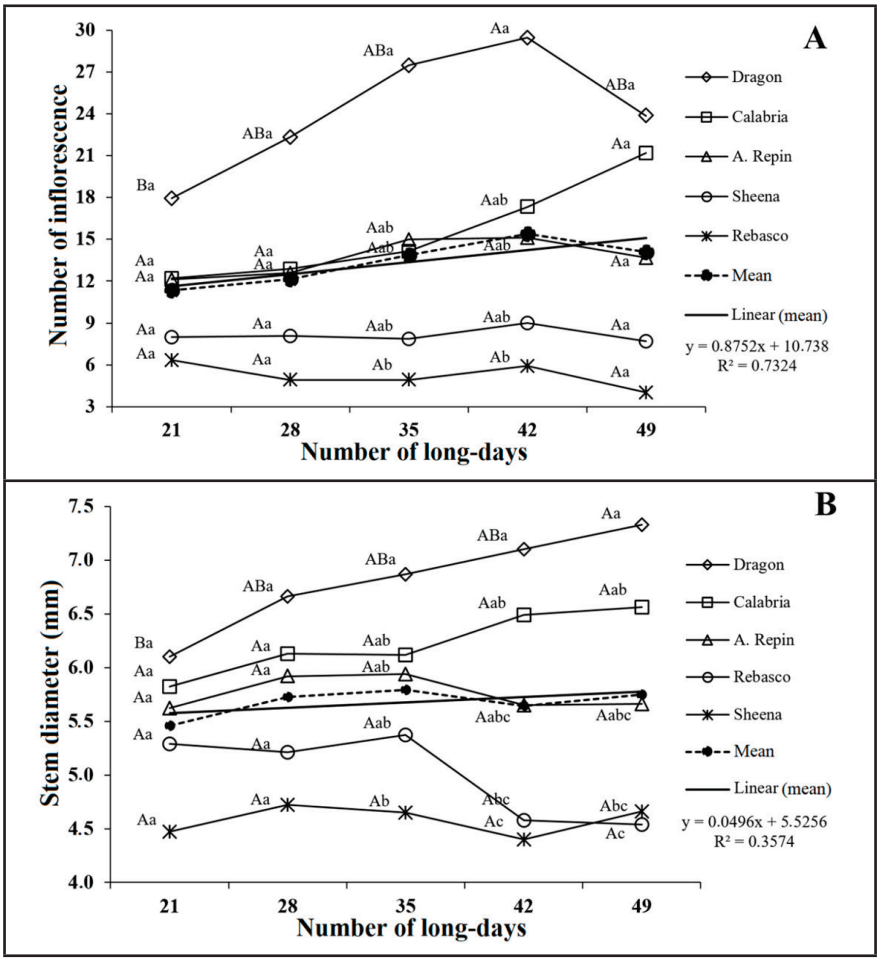


Figure 3. Averages of number of inflorescences (A), and stem diameter (B) of chrysanthemum cultivars grown under different number of long-days. Averages followed by the same capital letters (averages of the cultivar in different periods) and the same lowercase letters within the periods (among cultivars in the period) did not differ statistically among themselves by Tukey test, $p<0.05$. Viçosa, UFV, 2013.

Number of inflorescences

Dragon was the cultivar which most produced inflorescences in all long-days periods. This cultivar showed an increasing production, according to the increase of number of long days, except at 49 long days, when a decreasing in the total number of inflorescences, 17%, was verified. Sheena and Rebasco were the cultivars which produced fewer inflorescences in all long days evaluated in this study. Calábria was the only cultivar which showed an increase in total number of inflorescences, from 17 to 21 inflorescences per stem at 42 and 49 long days, respectively (Figure 3A). Mello *et al*. (2009) evaluated cut chrysanthemum cultivars at 28 long days. These authors observed that Calábria produced 12.7 inflorescences per stem, similar result was found in this study for the same cultivar Calábria (12.6 inflorescences). However, the cultivar Lameet Bright produced 6.9 inflorescences per stem, intermediate result for the evaluated cultivars Sheena (8.1 inflorescences) and Rebasco (5.0 inflorescences) (Figure 3A). Bellé *et al.* (2007) evaluated the cut chrysanthemum cultivar Gompier Chá at 32 long days and verified that this cultivar produced 9.4 inflorescences per stem, higher values only when compared to Sheena (7.9 inflorescences) and Rebasco (4.9 inflorescences) evaluated in this study (Figure 3A).

Stem diameter

The long-day periods affected differently the behavior of cultivars in relation to the stem diameter, it means, for Dragon and Calábria the increase in the number of long days promoted an increase in diameter, whereas for Rebasco and Sheena the longer the period of long days the smaller the

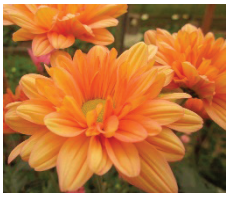
diameter of the stem. Apricot Repin and Rebasco showed a decrease in stem diameter at 42 and 49 long days (Figure 3B).

The cultivars at 21 and 28 long days did not show any significant statistical difference for stem diameter, by Tukey test ($p<005$). Despite the non-significance of the average test, an expressive difference among the cultivars was noticed. At 21 long days, the diameter ranged from 4.5 mm (Sheena) to 6.1 mm (Dragon) and at 28 long days, variation was even greater, from 4.7 mm (Sheena) to 6.7 mm (Dragon) (Figure 3B).

In general, the cultivars showed the same position of performance in all long-day periods, being Dragon, the cultivar which stood out producing stems with the greatest vegetative vigor and best agronomic quality. Sheena and Rebasco showed the lowest performance, though.

Thus, we concluded that the exposure to different numbers of long days provides differentiated responses of the cultivars, verified through the great difference in the long-day periods evaluated in this study. Nowadays, for cut chrysanthemum production, 35 to 45 long days is recommended (Barbosa, 2003). We could also observe that the cultivars used showed horticultural capability, even when produced under lower number of long days than the one found in literature. This fact indicates that a possible change in the number of long days can be recommended to produce cut chrysanthemum for the evaluated cultivars. Thus, more studies on the characterization of other cut chrysanthemum cultivars under different number of long days are necessary, in order to evaluate the possibility to reduce the production cycle, without affecting flowering quality.

Table 1. Description of cut chrysanthemum cultivars (*Chrysanthemum morifolium*). Viçosa, UFV, 2013.

Cultivar	Description	Color	Flower
Calábria	Medium cycle* (up to 8 weeks to flowering from the beginning of the short days), 96 days. Decorative inflorescences, considering that the ligulas decrease continuously from the edge to the center.	White	
Dragon	Medium cycle* (up to 8 weeks to flowering from the beginning of the short days), 96 days. Daisy-type inflorescences. Showing one or more layers of ligulated flower on the edges and the center of the flower head (pseudanthium or disk) is composed of very short tubular flowers, generally, colored differently from the ligulas.	Red	
Rebasco	Late cycle* (up to 9.5 weeks to flowering from the beginning of the short days), 106.5 days. Daisy-type inflorescences. Showing one layer of ligulated flower on the edges, with the yellow underside and the center of the flower head (pseudanthium or disk) composed of very short tubular flowers, generally, colored differently from the ligulas.	Red	
Sheena Branca	Late cycle* (up to 9.0 weeks to flowering from the beginning of the short days), 103 days. Spider-type inflorescences, showing tubular ligulas and smaller in the center.	White	
Apricot Repin	Medium/late cycle* (up to 9.0 weeks to flowering from the beginning of the short days), 103 days. Daisy-type inflorescences. Showing one or more layers of ligulated flower on the edges and the center of the flower head (pseudanthium or disk) is composed of very short tubular flowers, generally, colored differently from the ligulas.	Champagne	

Source: Adapted from Barbosa (2003). Photos of the author. *Considered from transplanting to harvest, with average supply of 40 long-days antecedent to short days.

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