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Flowering of *Euphorbia pulcherrima* Willd. ex Klotzsch var Valenciana under blue and red LED light

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ABSTRACT

Objective: To determine the effect of blue light (BL) and red light (RL), applied five hours at the end of the day (AED) and that of temperature, on the flowering of *Euphorbia pulcherrima* var Valenciana.

Design/Methodology/Approach: Three groups of plants were established under greenhouse conditions, all received sunlight (SL), AED one was under BL (460 nm) and another under RL (660 nm) with a photosynthetically active photon flux of 440 μmol m^{-2} s^{-1} and 550 μmol m^{-2} s^{-1} respectively; from the beginning of the experiment until 144 d later. In a second flowering cycle, residual effects of the treatments were evaluated.

Results: In the first flowering cycle, the appearance of cyathia and bract pigmentation under BL occurred on average at 177.5 d after initiation of the treatments, and under RL at 178 d. Compared to the application of SL alone (138 d) the process was delayed, on average 39 and 40 d, under BL and RL, respectively. No residual effects of the treatments on flowering were recorded.

Limitations on study/implications: It is necessary to evaluate other levels of temperature below and above the ones reported in this study, and also to increase and decrease the photoperiod.

Findings/conclusions: The prolonged delay in flowering can be attributed not only to the quality and intensity of light, but also to the photoperiod and the daytime temperature above that documented for flower initiation in var Valenciana.

Keywords: Photoperiod, light quality, late flowering, daytime temperature.

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INTRODUCTION

Light modulates metabolic, morphological and development responses in plants, among which there is flowering [1]; the effect on flowering is manifested fundamentally in species considered photoperiodic or dependent on the daily light duration to flower [2]. There are two groups of plants in function of their response to the photoperiod, which flower during long days and short nights (long day plants-LDP), and those that flower during short days and long nights (short day plants-SDP) [3].

Image by Ulises Moreno at Pixabay

The plants detect the characteristics of light through different families of photoreceptors, through which they adjust their growth and development in various environmental conditions [4].

Light management is very important in horticulture, to manipulate the growth and development of plants. Managing light has been made easy through the use of light emitting diodes (LED) technology. Through their management, it is possible to control desired responses in plants [5], such as: increasing the yield in crops, extending the production season, improving the quality of the product, and controlling the flowering of species sensitive to the day duration through management of the photoperiod [6]. *E. pulcherrima* or poinsettia is considered a national plant genetic resource, important as germplasm for research, genetic improvement and commercial exploitation [7]. On the other hand, its commercial use is mainly ornamental, but there are records of its use in fields such as Chinese traditional medicine [8]. Likewise, there are studies of the potential use of some of their metabolites or the total extract of leaves and bracts, as agents of disease control in plants [9].

The objective of this study was to generate information that can contribute to already existent studies on poinsettia, and for this, the effect of the extension of the photoperiod in five h at the end of the day (AED) was evaluated under two qualities of LED light, blue (BL-460 nm) and red (RL-660 nm), on flowering and pigmentation of bracts of *E. pulcherrima* var. Valenciana (in this variety they happen simultaneously), since both light components can be manipulated and are of great impact in flowering of this plant, as a result of their condition of having long night photoperiods.

MATERIALS AND METHODS

The experiment was established in a greenhouse with glass cover that is located in the Universidad Autónoma Chapingo (Coordinates: 19° 29' 23" LN and 98° 53' 37" LW; 2250 masl). During the research period the average, minimum and maximum temperatures were: 17.85, 10.1 and 30.24 °C in the first year and 18.2, 10.5 and 30.6 °C in the second, respectively. The average relative humidity was 62.6% in the first year and 60.8% in the second. The data were recorded through two HOBO®, model MX2300 tem/RH, ONSET 1-800-LOGGERS.

The experiment was conducted with already rooted cuttings of *E. pulcherrima* var. Valenciana, from Tetela del Monte, Morelos. Previous to light treatments, the shoots were trimmed to leave plants with four internodes. The plants were placed in black polyethylene bags with capacity of four liters. A substrate formed by a mixture of soil with pine-oak litter and worm castings in 3:1 proportion was used. In the transplant a root development promotor (ROOTEX®) was applied, and then two applications in eight-day intervals.

Light sources and treatments

Light was supplied with monochromatic LED lamps for use in horticulture (LED Grow Light, E27). Blue light (BL; All Blue 460 nm; 36W) and deep red (RL; All Deep Red 660 nm; 36W) were used.

Blue light (BL) and Red light (RL) were applied from 18:00 h and until 23:00 h. The photosynthetically active photon flux that was supplied with BL was 440 μmol m^{-2} s^{-1} and with RL it was 550 μmol m^{-2} s^{-1}. The control treatment plants received only sunlight (SL= 109 μmol m^{-2} d^{-1} (daily integral light)).

The Photosynthetic Photon Flux Density (PPFD) was measured in the center of the light source and at a distance of 20 cm from the plant canopy, through a Quantum Meter (Model QMSW-SS, Apogee Instruments, Logan, UT). The treatments began on July 28 and ended in December 19, 2019 (144 days). The lamps were placed 20 cm above the plant canopy. To conserve this distance, the lamps were elevated as the plants grew.

Twenty-four (24) experimental units were established, eight for each treatment. Each unit was made up by three plants, with a separation between units of 50 cm. The experimental units that received the BL and RL treatments were isolated with polyethylene curtains of double color: white inside and black outside. The curtains stayed open during the day for all the plants to receive SL that falls on the greenhouse.

Evaluation of flowering times and bract pigmentation

The analysis and the comparison of the flowering times of poinsettia plants that developed under different lighting conditions were conducted through the so-called Survival Analysis (SA) [10]. The SA allows evaluating the occurrence and time when an event takes place [11], as is the case of flowering [12]. The event that was recorded was the appearance of cyathia and bract pigmentation, since it is an indication of the start of flowering in poinsettia plants.

Applying the SA allowed to: a) define the type of distribution and the functions of probability associated to the starting times of flowering and bract pigmentation; b) statistically compare the distribution of flowering times and bract pigmentation in plants exposed to the three lighting conditions; and c) estimate a regression model with the aim of evaluating the effect of the three lighting conditions in starting times of flowering and bract pigmentation. In addition, with the SA the statistical model that best represented the distribution of the times of occurrence was found and inferences to obtain the regression model were made based on it [13].

Distribution of starting times of flowering and bract pigmentation

By virtue of the presence of cyathia, the distribution and the probability function associated to flowering was recorded, obtained through the SAS LIFETEST procedure [14]. The comparison of the distributions of flowering times in plants exposed to the three lighting conditions was carried out through the Log-Rank test [11].

The effect of lighting conditions on the times of flowering and bract pigmentation was evaluated with a maximum likelihood parametric regression through the SAS LIFEREG procedure [14]. To compare the effect of the three lighting conditions, the condition of only SL was selected as reference variable. The coefficients of regression and their standard errors ($\beta_i \pm$SE) were improved based on a goodness of fit test, which allowed establishing the type of distribution that adjusted more to the starting times of flowering. The distribution

observed was compared with the theoretical Weibull, Exponential, Gamma, Log-logistic and Log-normal distributions [11].

According to Allison [11], the coefficients of regression (β_i) obtained were transformed based on the relationship $e^{\beta i}$. The result estimated the change in average time of flowering and bract pigmentation, under BL and RL conditions, in relation to the condition of only SL.

RESULTS AND DISCUSSION

The light environment of the greenhouse modified the times of flowering and bract pigmentation of poinsettia plants. The variety used, called sun variety, begins flowering at the beginning of October, under the experiment's conditions, and this process happened until the second week of December of the year 2019.

The plants that were subjected only to SL presented a distribution of times of flowering and bract pigmentation that was statistically different than the one presented by the plants subjected to BL ($\chi^2=47$; d.f.$=1$; $p<0.0001$) and RL ($\chi^2=47$; d.f.$=1$; $p<0.0001$). However, between BL and RL no significant differences were found in flowering times ($\chi^2=0.6$; d.f.$=1$; $p=0.438$). On average (± standard error), the flowering time of plants subjected only to SL (20±0.01) was six weeks shorter than the ones exposed to BL (25.87±0.193) and RL (26±0.209) (Figure 1A).

The estimated regression model (Table 1) indicates that the times of flowering and bract pigmentation presented statistically significant increments when the RL and complementary BL were applied. In both cases, the average increase of flowering time was estimated to be close to 30%.

In the year 2020 the same plants, which were no longer subjected to the addition of LED light, presented a distribution of flowering times significantly different to that presented in 2019 ($\chi^2=150.9$; d.f.$=1$; $p<0.0001$). In contrast to what happened in 2019, when the average flowering time (± s. e.) was 23.9 (±0.345) weeks, in 2020 it was only 13.07 (±0.163) weeks (Figure 1B).

The delay in flowering and bract pigmentation of the Valenciana var. under lighting treatments can be related not only with the photoperiod, but also with the quality and intensity of the light, as well as with the temperature. Poinsettia is a plant considered to be of long nights. Ecke III *et al.* [15] indicate that the flowering initiation requires a critical duration of the night longer than 11 h and 40 minutes and in particular Galindo-García *et al.* [7] report that this variety requires more than 11 h of darkness, for flowering initiation. Increasing the lighting period by five h (8 of darkness) was, possibly, one of the factors that contributed to the delay in flowering. The cyathia were visible and bract pigmentation started in the month of January, events that ought to happen the first week of the month of October, since most of the ecotypes of sun variety poinsettia, such as the Valenciana var., are called premature [7].

It should be pointed out that the number of long nights to which the plant is exposed is decisive. Kannangara and Hansson [16] subjected *E. pulcherrima* to conditions of short days for three weeks and then to continuous light, which prevented the production of flower primordia or bract pigmentation, while another group of plants, under four

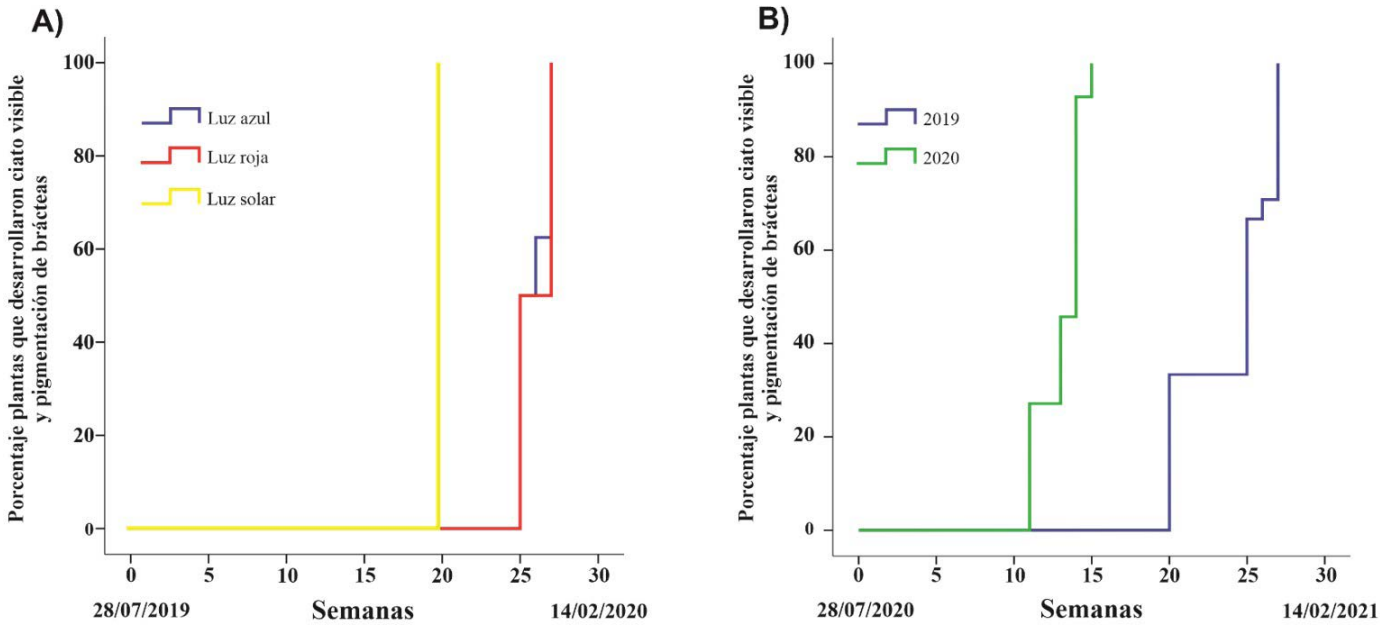

Figure 1. Distribution of the times of flowering and bract pigmentation of *E. pulcherrima* var. Valenciana. A) Distribution of the times of flowering and bract pigmentation under two lighting conditions: BL, blue light and RL, red light; without extension of the SL photoperiod, sunlight. B) Distribution of flowering times and two evaluation cycles. In 2019 plants that were subject to the extension of the photoperiod with BL and SL were considered, and in 2020 the same plants without extension of the photoperiod.

Table 1. Maximum likelihood regression model for the flowering times of *E. pulcherrima* var. Valenciana, under only SL, BL and RL. The condition of SL was considered the reference variable. The parameter ebi indicates the proportion of change in the flowering time in relation with the reference variable. It was considered that the flowering times have a Log-logistic distribution.

Parámetro	G. l.	$\beta_i \pm$e. e.	$e^{\beta i}$	χ^2	Pr>χ^2
Intercepto	1	2.996 ± 0.004	.	553691	<0.001
LA	1	0.2543 ± 0.0059	1.29	2382.44	<0.001
LR	1	0.2616 ± 0.0058	1.30	2503.54	<0.001
LS	0	0			
Escala	1	0.019 ± 0.002			

weeks of short days, did flower. This indicates that a specific amount of time is required in short days for flowering and could explain why in the Valenciana var., flowering under BL and RL happened three weeks after interrupting the treatments and increasing the hours of darkness.

Temperature is another factor that could be related to the extension of the vegetative period in the Valenciana var., by virtue of it being considered decisive for flowering [15]. For Schnelle *et al.* [17] the initiation stage of flowering seems to be very sensitive to high temperatures which can cause its delay ("delay from heat"). In this study the average daytime temperatures, in the last week of September, when flower induction should have happened [18], were up to four degrees higher than the ones recommended for this stage, 20-22 °C according to Ecke III *et al.* [15]. In this sense, Runkle and Heins [19] indicate

that above the optimal temperatures, flowering initiation can present "delay from heat"; on the other hand, Berghage and Heins [20] point to the delay from heat making synergy with the reduction in the number of hours of darkness.

In the second cycle of flowering and bract pigmentation, without extending the photoperiod, a delay in flowering was found, without significant differences between treatments. In the plants that had been under only SL the events happened in the third week of October (it could said to be one week of delay) and in the plants that had been under BL and RL (extended photoperiod) they happened in the first and second week of November (delay of three weeks). The delay in this second cycle could be attributed to temperatures above those recommended for flowering induction.

Finally, the third factor that possibly contributed to the delay of flowering is the quality of light (light spectrum). Craig and Runkle [3] describe that flowering of long-night plants can be inhibited with night lighting, without defining a spectrum capable of controlling, since the times of exposure and its quality have different effects. Runkle [21] points out that at a high intensity, 20 μmol m^{-2} s^{-1} or more, BL can inhibit flowering of short-day plant, although changes were also detected in function of the time of exposure, the moment of the day when it is applied, or both [22].

Flowering of *E. pulcherrima* can be affected by the RL AED, although the same as with BL, its effect is in function of its proportion, intensity and time of exposure [23]. Islam *et al.* [24], for example, report that the appearance of cyathia and bract pigmentation was not affected when subjecting two poinsettia varieties to 30 min of low radiation RL (5 mol m^{-2} s^{-1}) AED; however, Zhang and Runkle [23] report that four h AED of a high proportion of red: far red light (0.73:0.04), plus two h of far red (six h in total), delayed flowering of two cultivars of poinsettia.

Therefore, the delay in time of flowering and bract pigmentation of the Valenciana var., as pointed out by Kami *et al.* [25], could be the joint result of high daytime temperatures, the photoperiod, the quality and the light intensity.

CONCLUSIONS

The extension of the photoperiod by five h, the daytime temperature above 24 °C in the flowering initiation period, and the red or blue lighting do not favor flowering of *E. pulcherima* Valenciana var., for its sale as ornamental plant in the December season.

Daytime temperatures above 24 °C during flowering initiation, in addition to the expansion of the photoperiod, as well as light quality and intensity, were able to exercise synergy and delay for a long time (39 and 40 d, under blue and red light, respectively) the flowering and bract pigmentation of *E. pulcherrima* var. Valenciana.

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