The effect of LED illumination on flower differentiation of strawberry short-day cultivars in winter production season

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Abstract

Plants such as tray and mini-tray (in replace of bare-root plants) and artificial assimilation lighting systems on strawberry tunnels have been used to ensure better crop productivity and to increase the competitiveness of the Portuguese strawberry sector. In order to observe if LED (light emitting diodes) supplemental illumination will affect flower differentiation and development of short-day strawberry cultivars in southern Portugal, a field trial was established with tray and mini-tray plants of 'Dream' and 'Darselect' cultivars, grown under and without LED light (deep red/white/far-red). The artificial lighting was applied from October to January in complement to natural daylight keeping 16 h day^{-1} photoperiod. Plant architecture was established by plant dissection into crowns, leaves, inflorescences, flowers and fruits, and all the meristems of apical and lateral shoots were counted and distinguished as vegetative or reproductive. Tray plants were significantly more vigorous than mini-tray plants. Through meristems observation it was found that both cultivars developed inflorescences and flowers primordia that were differentiated in the nursery and no new differentiation occurred at 50 days after plantation (DAP). Afterward, flower differentiation took place again till the end of the growing season (110 DAP). LED light did not improve flower development during the first growing season. Although plants stop fruiting in January the apical meristems were in high activity. Further studies should be done to determine the flowering differentiation pattern throughout the first and second tray plant crop.

Keywords: floral architecture, *Fragaria* × *ananassa*, mini-tray, tray, substrate culture

INTRODUCTION

In Portugal, strawberry production area decreased over last 10 years. The interest in this fruit production has dropped dramatically due to price reduction, lower in comparison to other berry fruits, as well as, to the high competition of the Spanish market. To improve the Portuguese strawberry industry the area of winter fruit production must increase focus on high berry prices for the export market and plants such as tray and mini-tray (in replace of bare-root plants) must be used as they require less irrigation for plant establishment and grow faster than bare-root plants (Hochmuth et al., 2006).

Tray propagation techniques in the nursery must provide adequate conditions for flower induction and differentiation in late summer and early fall to optimize fruit production and quality during winter. Several studies related to strawberry architectural behaviour have proved that this method is as an effective tool in evaluating tray plant quality and also as predicting the timing and the extent of the potential harvest (Savini et al., 2004; Massetani and Neri, 2016; Valdiviesso et al., 2019). The plant architecture is represented as extended axes on which vegetative and reproductive organs (visibles and primordia) are drawn with different symbols and colours (Savini et al., 2005).

Strawberry flower initiation and development depends on photoperiod and temperature effects. Short day (SD) cultivars initiate flower buds on short day conditions. At

temperatures less than 15°C they become facultative short day plants (Darrow, 1966). Long days repress inflorescence initiation but do not affect the development of previously initiated inflorescences (Manakasem and Goodwin, 2001). Artificial lighting has been used for out-of-season production in greenhouse systems. For breaking dormancy, strawberry plants can be subjected to supplemental artificial lighting for day lenght extension, causing plant elongation (Lieten, 2005). In natural light limitations namely in late autumn and winter supplemental artificial lighting is used to stimulate photosynthesis (Palha et al., 2019). The application of LEDs is more common and more efficient over traditional forms of horticultural lighting because of their small size, durability, wavelength specificity and lower power consumption.

This research aimed to understand the effects of LED supplemental light on the flower differentiation and flower primordium development of tray and mini-tray plants of SD cultivars planted in early fall through plant architectural analysis, during the autumn and winter protected crop cycle.

MATERIALS AND METHODS

The experiment was set up in four high plastic multi-tunnel with an area of 180 m^2 each one (6×30 m) located in the Algarve region (37°06'33"N; 7°42'34"W). This region has excellent climatic conditions (mild winter) for early production of strawberries.

The experimental methodology used combinations of 2 light treatments (no LED and with LED), 2 nursery plant type (mini-tray and tray) and 2 SD cultivars ('Dream' and 'Darselect') with 5 replicates, and 4 sampling dates using a total of 160 plants for architectural analysis.

For light treatments two tunnels had no lamps (without LED) and the other two had a total of 20 per tunnel (with LED). Artificial lighting was provided by 'Philips GreenPower LED flowering' (deep red/white/far-red; 20 μmol s^{-1}), from October to January in complement to natural daylight keeping 16 h day^{-1} photoperiod.

Tray and mini-tray plants from the same nursery were planted in substrate bags containing coconut fibre (100%), in double rows, 7 plants m^{-1} bag^{-1}, corresponding to 8.2 plants m^{-2}. Planting date was on September 26, 2019.

Plant architectural analysis was done at 0 DAP (September 26) 50 DAP (November 12), 75 DAP (December 9) and 110 DAP (January 13). Macro observations were obtained by counting crown, leaf, inflorescence and flower and fruit number. Leaf number included expanded and unexpanded leaves. Meristems observations (micro) were assessed under a stereomicroscope (40× magnification) and the primordia leaves and all the meristems of the apical and lateral shoots were counted and distinguished as vegetative or reproductive.

The inflorescence developmental stages at the apical meristems were evaluated in the nursery plants according to Valdiviesso et al. (2019): 0 = vegetative apex; A = doming up of the apical dome/flower induction; B = beginning of flower primordium visible/flower differentiation; D = floral pieces development (stamen and carpel); G = floral pieces visible but immature; H = mature flower.

To evaluate the nursery plants (0 DAP), 6 plants of each cultivar and plant type were sampled before planting to determine plant dry biomass (roots, crowns, leaves and flowers). Dry weight was recorded after oven drying the fresh material at 70°C for 72 h.

Fruits were harvest 2 or 3 times per week on a complete row with 210 plants with no replicates and started on November 8 until January 20. At each harvest, fruits were separated into marketable and unmarketable berries and were weighted and counted.

All data (excepting harvest data) were subjected to analysis of variance (ANOVA) and the differences were compared using mean separation by Tukey test (α=0.05) using Statistics 9.0 program (Analytical Software, Tallahassee, Florida).

RESULTS AND DISCUSSION

Nursery plant characteristics

Before planting (0 DAP) no differences on vegetative parameters (macro and micro) were detected between plant type on both cultivars (Table 1). All tray and mini-tray plants

had one crown and 3 to 4 leaves plant^{-1}. During nursery all plants differentiated 2-3 inflorescences and 8-9 flowers but the flower differentiation was in different stages. For 'Darselect' flower differentiation stages were similar between tray and mini-tray plants while for 'Dream' most of tray plants were in the stage G and mini-tray in D which means that 'Dream' tray plants were in a more advanced stage of flower differentiation (Figure 1).

Table 1. Mean number (±SE) of macro and micro parameters for tray and mini-tray plants in 'Dream' and 'Darselect' cultivars, before planting.

Cultivar	Plant type	Macro parameters no.		Micro parameters no.		
		Crowns	Leaves	Leaves	Inflorescences	Flowers
Dream	Tray	1.0	4.2 (±0.8)	2.4 (±1.3)	2.4 (±1.1)	8.0 (±2.9)
	Mini-tray	1.0	4.4 (±0.6)	3.0 (±1.4)	3.2 (±1.1)	8.8 (±3.3)
Darselect	Tray	1.0	2.6 (±0.0)	1.6 (±0.9)	2.8 (±0.8)	8.6 (±2.8)
	Mini-tray	1.0	4.0 (±0.6)	2.6 (±0.6)	3.2 (±0.8)	9.4 (±2.7)

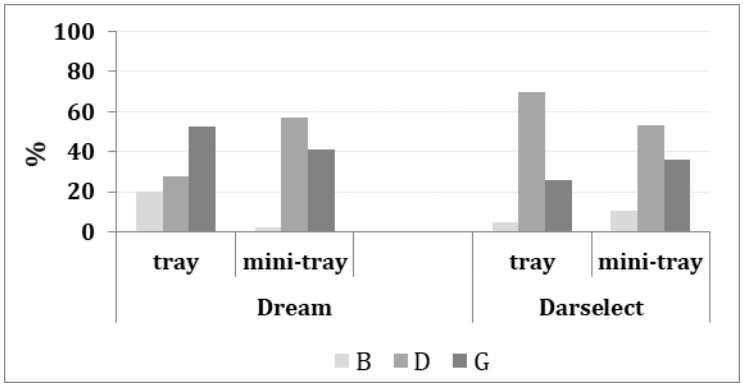

Figure 1. Flower differentiation stages for 'Dream' tray and mini-tray plants and for 'Darselect' tray and mini-tray plants. Percentage represents the number of buds in each stage on total number of buds plant^{-1}.

Tray plants were more vigorous than mini-tray plants. For both cultivars the total plant dry weight was higher in tray plants having more roots and crown biomass (Table 2). 'Dream' mini-tray had the smallest plant dry biomass.

Table 2. Dry weight of tray and mini-tray plants in 'Dream' and 'Darselect' cultivars, before planting.

Cultivar	Plant type	Dry weight (g)			
		Roots	Crowns	Leaves	Total
Dream	Tray	3.3^{a}	1.6^{a}	0.8^{a}	5.9^{a}
	Mini-tray	1.5^{b}	0.6^{b}	0.3^{b}	2.4^{c}
Darselect	Tray	3.9^{a}	2.1^{a}	0.6^{a}	6.6^{a}
	Mini-tray	2.4^{b}	1.0^{b}	0.7^{a}	4.2^{b}

Significance within columns according to Tukey test ($p<0.05$)

Fruit production

Plants restart to grow immediately after planting, expanding and producing new leaves and developing new crown branches and previously initiated inflorescences and flowers. Previous studies have reported that containerized plant typically provide for quicker establishment and enhance early growth and flowering compared with bare-root plants (Hochmuth et al., 2006; Palha et al., 2012). Flowering and fruiting increased from October till

December and decreased afterward until the end of the growing cycle (end of January) which corresponds to the first production season (autumn-winter).

For both cultivars total yield was not affected by LED light (Table 3). 'Dream' tray plants produced more than mini-tray plants. In fact, tray plant size was larger than mini-tray plants. For 'Darselect' the yields were quite similar between the two types of plants.

Table 3. Total yields and fruit number and weight of 'Dream' and 'Darselect' for different plant type and LED light treatments.

Cultivar	Plant type	Light	Yield (g plant^{-1})	Fruit no.	Fruit weight (g)
Dream	Tray	LED	218.6	17.2	12.7
		No LED	167.9	10.3	16.4
	Mini-tray	LED	83.9	8.3	10.1
		No LED	73.7	6.5	11.3
Darselect	Tray	LED	247.5	15.3	16.2
		No LED	188.8	13.7	13.8
	Mini-tray	LED	262.1	18.1	14.5
		No LED	256.1	17.4	14.8

In field plant architecture

Leaf growth, crown branching and inflorescences growth continued during October and beginning of November, but plant architecture at 50 DAP revealed that there was no meristematic activity. It was found that no new flower differentiation occurred for all treatments, cultivars, plant type and LED light (Figure 2 and 3). All the meristems in the main and in the lateral shoots were in vegetative stage. Therefore, yield during the fall comes from differentiated inflorescences in the nursery confirming the importance of tray plant quality in the propagation phase for the first tray production season (Savini et al., 2004).

Observations at 75 DAP indicated that following the meristems vegetative stage period, plants started again to differentiate reproductive meristems and the number increased until January when the harvest ended. This flowering differentiation pattern was similar in all treatments (Figures 2 and 3). These results agree with Patricio (2019) who also found the same flowering pattern with frigo tray plants of several SD cultivars planted in late September.

At 110 DAP, the number of inflorescences primordia varied between 3.0 and 7.6 inflorescences plant^{-1} (Figures 2 and 3). The effects of LED light, cultivar and plant type on this parameter was not consistent. Between tray and mini-tray plants the number of inflorescences plant^{-1} presented by 'Dream' was respectively 6.6 and 4.9 while for 'Darselect' it was 5.8 and 6.3.

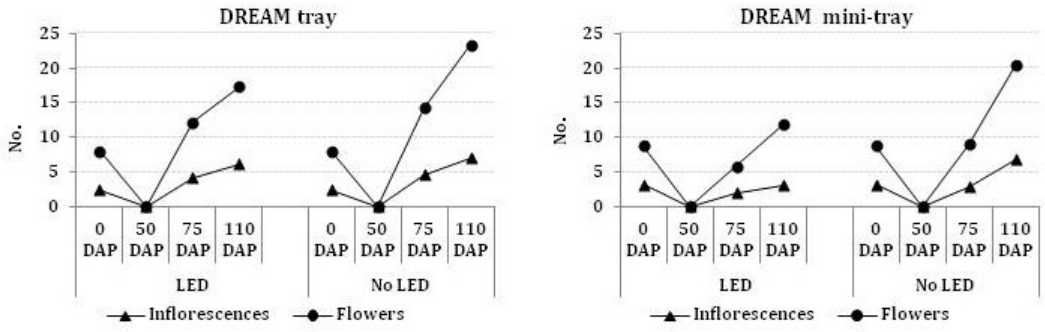

Figure 2. Number of differentiated inflorescences and flowers of tray and mini-tray plant, with LED and no LED for 'Dream' cultivar during growing cycle.

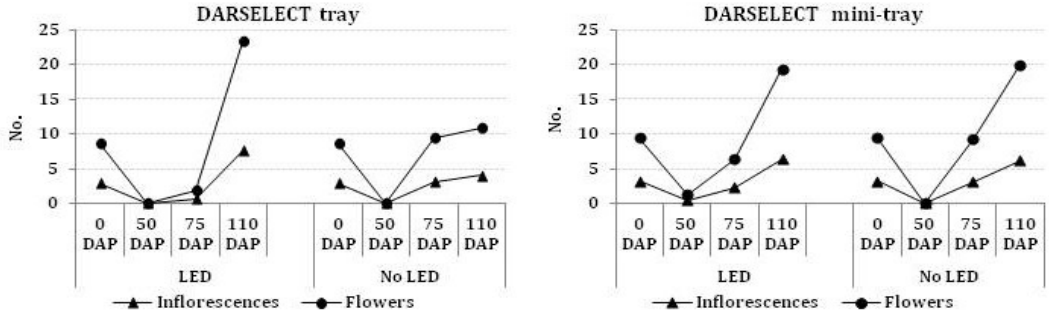

Figure 3. Number of differentiated inflorescences and flowers of tray and mini-tray plant, with LED and no LED for 'Darselect' during growing cycle.

Strawberry vegetative growth and flowering is predominantly controlled by temperature and photoperiod. In this study increasing the number of hours to 16 h did not improve the development of flowers and fruits during the fall and winter of SD cultivars. Long days did not affect also the inductive flower phase to stimulate meristematic differentiation. This could be explained by the occurrence of mild temperatures during autumn and winter in Algarve region which allows the SD cultivars to initiate flower buds.

These results suggest that although plants stop fruiting the apical meristems were in high activity. In tray production technology a second production can be obtained in spring so future studies should be programmed to examine the flower differentiation pattern on first and second tray plant cropping season.

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Literature cited

Darrow, G.M. (1966). The Strawberry: History, Breeding and Physiology (New York, NY: Holt, Rinehart and Winston), pp.447.

Hochmuth, G., Cantliffe, D., Chandler, C., Stanley, C., Bish, E., Waldo, E., Legard, D., and Duval, J. (2006). Fruiting responses and economics of containerized and bare-root strawberry transplants established with different irrigation methods. HortTechology *16* (*2*), 205–210 https://doi.org/10.21273/HORTTECH.16.2.0205.

Lieten, P. (2005). Strawberry production in central Europe. Int. J. Fruit Sci. *5* (*1*), 91–105 https://doi.org/10.1300/J492v05n01_09.

Manakasem, Y., and Goodwin, P.B. (2001). Responses of dayneutral and Junebearing strawberries to temperature and daylength. J. Hortic. Sci. Biotechnol. *76*, 629–635 https://doi.org/10.1080/14620316.2001.11511422.

Massetani, F., and Neri, D. (2016). Strawberry plant architecture in different cultivation systems. Acta Hortic. *1117*, 291–296 https://doi.org/10.17660/ActaHortic.2016.1117.47.

Palha, M.G., Campo, J.L., and Oliveira, P.B. (2012). Strawberry plant growth and dry matter partitioning as influenced by planting date and plant type in an autumn production system. Acta Hortic. *926*, 463–469 https://doi.org/10.17660/ActaHortic.2012.926.65.

Palha, M.G., Pestana, F., and Oliveira, C.M. (2019). Plant growth, yield and fruit quality of *Fragaria* × *ananassa* genotypes under supplemental LED lighting system and substrate cultivation. Acta Hortic. *1265*, 91–98 https://doi.org/10.17660/ActaHortic.2019.1265.13.

Patricio, S.C. (2019). Avaliação do potencial de plantas 'tray' de morangueiro. Arquitetura floral e produtividade. Dissertação para a obtenção do Grau de Mestre em Engenharia Agronómica (ISA/UL), pp.75.

Savini, G., Letouzé, A., Sabbadini, C., and Neri, D. (2004). Evaluation of tray-plant quality in the propagation phase. Acta Hortic. 231–236.

Savini, G., Neri, D., Zucconi, F., and Sugiyama, N. (2005). Strawberry growth and flowering. An architectural model. Int. J. Fruit Sci. *5* (*1*), 29–50 https://doi.org/10.1300/J492v05n01_04.

Valdiviesso, T., Vieira, A., Patrício, S., Oliveira, C., Oliveira, P.B., Palha, M.G. (2019). Arquitetura da planta do morangueiro. Vida Rural *1847*, 42–44.