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Influence of various photoperiods on enhancing the flowering time in chrysanthemum (*Chrysanthemum morifolium*)

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Abstract

The experiment was conducted to evaluate the impact of various photoperiods on plant height, number of branches, leaves, suckers, flowers per plant, leaf area, days to flowering, flower size, flower fresh weight and blooming period. The photoperiods studied include control (natural light hours), 12 hour, 10.5 hour, 9 hour and 7.5 hour. Terminal cuttings were planted in 28 cm pots individually on 5th March. On 2nd May, plants were covered with black cotton cloth fixed on boxes (each box having 240 cm length, 120 cm width and 120 cm height) to create dark effect. All the pots were placed in the greenhouse where temperature ranging 20 to 25°C under the cloth boxes to create different regimes of photoperiods. Data indicated that 9 hour photoperiod was superior with days to flowering (121 days), and flower size (4.8 cm), than the rest of photoperiods. Moreover 9 hour photoperiod produced less branches (6.5), suckers (3.7), number of flowers (8), number of leaves (24) and blooming period (27 days). Amongst the other photoperiods, 10.5 hour daily light interval performed well and was close to 9 hour daily light interval with days to flowering (129 days), flower size (4.9 cm) and flower fresh weight (3.3 g). It was concluded that 9 hour photoperiod was superior closely followed by 10.5 hour photoperiod which produced flowers off season with prolonged flowering time.

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Introduction

Chrysanthemum is one the leading cut flowers in the international market. Chrysanthemums are herbaceous perennial plants grown mainly as cut flowers, but also used as potted flowering plants or bedding plants. Modern cultivars are available in a range of colour combinations and petal styles (spider, incurved etc). Their demand is at peak during Christmas, Easter, holidays (Biondo and Noland, 2000; Dole and Wilkins, 2005). It is a short-day plant.

Flowering is the end result of physiological processes, biochemical sequences and gene action responding to the influence of environmental stimuli (photoperiod, temperature) and the passage of time (Munir *et al.,* 2004; Zheng*et al.,* 2006). The processes offlower induction takes place in the leaf (O'Neil, 1992) and result in floral initiation in which the apical meristem changes towards floral development (McDaniel *et al.,* 1992). It is also believed that flowering is induced by a stimulus (florigen), which is produced within the leaf (Turck *et al.,* 2008), but this hormone has not yet been identified (Baloch *et al.*, 2009). When the apical meristem of the plant is committed to flowering, its fate becomes irreversible (Bernier, 1988), although flower or inflorescence reversion to vegetative growth can occur spontaneously in some species. This condition can be caused if plants are transferred to certain specific photoperiod or temperature regimes, which favour vegetative development (Batteyand Lyndon, 1990).

Light requirement for a plant or photoperiod is measured by the biological clock (circadian rhythm) within the leaves (O'Neil, 1992) and in response release a stimulus to the apex to induce flowering (McDaniel, 1996; Corbesier and Coupland, 2005). Under natural conditions, however, plants under leaf canopy experience not only reduction in light but also alter spectral light quality due to the selective filtering of blue and red wavelengths by chlorophyll (Schmitt and Wulff, 1993). Plants grow in dense stands in non shaded location use R:FR signal to compete with the neighbors for light (Vandenbussche*et al.*, 2005).Shade avoiding plants have mechanism that reacts quickly to changes in R:FR ratio that are sensed by the phytochrome (Franklin and Whitelam, 2005). Plants grown under low light etiolate and subsequently accelerate flowering time (Cerda and Chory, 2003; Pierik*et al.*, 2004).

Flowering is controlled by the reduction of day length in chrysanthemum (Dole and Wilkins, 2005). Twelve hour or less photoperiod is required for flowering and 14 hours or more for vegetative growth (Larson, 1992; Dole and Wilkins, 2005). The day length should be changed in a timely manner depending on the season. In summer short days are created artificially by covering the plants for part of each day with a black cloth to promote flowering (Wieland, 1998; Janick, 2008). Chrysanthemums can be grown during autumn to initiate flowering. When nights get longer than nine hours, they begin to set flower buds (Nxumalo and Wahome, 2010). Greenhill (2008) reported that the minimum number of continuous short days required to produce quality blooms is cultivar dependent.

Keeping in view the above facts an experiment was designed to evaluate a suitable artificial photoperiod interval which can initiate flowering even in the long days with the objectives to evaluate suitable photoperiod to achieve off season flowering in chrysanthemum and to make the flower available for maximum duration of the year.

Materials and methods

Experiment was performed at Hazara Agriculture Research Station, Abbottabad, Khyber Pakhtunkhwa, Pakistan during 2010-11 to evaluate the effect different photoperiods on chrysanthemum flowering and related plant characters. The experiment was conducted as a Completely randomized block design with five treatments replicated 4 times.

Plant materials

Terminal cuttings of chrysanthemum were taken from the stock and were planted in 28 cm diameter pots individually on 5th March. The pots were filled with 2 parts leaf mold and one part silt. Fertilizer NPK was applied at the rate of 1.5 g per pot. On 2nd May, four boxes were made of wooden bars and covered with black cotton cloth to create dark effect, each having 240 cmlength,120 cm width and 120 cm height.

The black cloth was fixed on the structures to create dark effect. All the pots of different treatments were placed in the greenhouse in temperature ranging 20 to 25°C at day under the black cloth boxes to create different regimes of photoperiods.

The greenhouse at Hazara Agriculture Research Station is equipped with heating and cooling systems. The covers were applied every day in the evening with 1.5 hour difference except in control. The covers were removed from all treatments at 6: 00 am to start photoperiod. Five pots were placed in each treatment and were rotated continuously after every five days.

Treatments

The photoperiods applied on plants werecontrol (Natural conditions), 12 hour light 12 hour dark, 10.5 hour light 13.5 hour dark, 9 hour light 15 hour dark and 7.5 hour light and 16.5 hour dark

Data analysis

All the cultural practices were kept uniform for each treatment. The experiment was repeated in 2011 and average data of both years were analyzed at the end providing year wise detail and interaction between year and photoperiod was calculated using computer statistical software "Statistix 9.0". (www.statistix.com). Statistical significance is given at $p < 0.05$.

Vegetative characters

The physical traits considered included plant height which was the measure of stem length from the crown to the top of the stem. The number of branches plant^{-1} grown on plant were counted and recorded after the last flower harvested. All the leaves grown on plant were counted and recorded after the last flower harvested. Leaf area was measured with the help of an automatic Leaf Area meter (Model, Delta- T Devices Ltd., Burwell Bs, UK).

Flowering characters Days taken to flowering were counted from date of planting of cuttings (5th March) to the date of flower bud opening.

The number of flowers, flower size (diameter) and fresh weight were then taken after harvest. All flowers grown on the main stalk and the side branches were counted up to the last flower harvested. For blooming period number of days from flower bud break till its petal fadding were counted. The flower size was recorded by measuring the diameter of the flower in cm. Full bloomed flowers were excised and weighed on electronic balance individually.

Results and discussion

Vegetative characteristics

Plant height (cm)

Various photoperiods (control, 12, 10.5, 9 and 7.5 hour) showed significant effect on plant height, while year and photoperiod interaction did not affect the plant height. Plant height reduced with the decrease in photoperiod. Maximum plant height (83.3 cm)was achieved with 12 hour light, and control (81.2cm) respectively, while it was lower (64.4cm) in 10.5 hour photoperiod. Photoperiod of 7.5 hour had significantly different effect as compared to other treatments (Table 1).

The higher plant height achieved by the plants that were not covered might be the result of higher light intensity. The high light intensity could have contributed to the higher photosynthetic activity of the plants. Long days help to maintain vegetative growth of stock plants and cuttings prior to placing young plants under short-day conditions for flowering (Larson, 1992; Dole and Wilkins, 2005). In contrast plants treated with the shorter photoperiod (due to less light duration) might have converted food reserves to flower bud initiation and had significantly lowered the height. These findings have been confirmed by Nxumalo and Wahome (2010) who recorded maximum height in control in chrysanthemum and Vrsek*et al.* (2006) in aster where they noticed taller plants under longer photoperiods.

Total number of branches plant⁻¹

Higher number of branches (8) were recorded in untreated plants compared to (6) in plants placed under (7.5, 9 and 10.5) hour photoperiods. Effects on plants in control and those treated with 12hour were significantly different from plants placed under 7.5, 9 and 10.5hour photoperiods. Plants placed under 7.5, 9 and 10.5 hour photoperiods produced same number of branches per plant (Table 1).

Table 1. Effect of photoperiods on plant height, number of branches/plant and number of suckers/plant in Chrysanthemum for year 1 (2010) and year 2 (2011).

Photo – period (hour)	Plant height (cm)			Number of branches/plant			Number of suckers/plant		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Control	83.6 a	78.9 ab	81.2 a	7.8	8.1 a	8.0 a	7.3 a	7.0 a	7.2 a
12	84.1 a	82.6 a	83.3 a	7.0	7.6 ab	7.3 a	5.4 b	6.0 b	5.7 b
10.5	66.5 b	62.3 c	64.4 c	6.7	6.3cd	6.5 b	3.8 d	4.1 c	4.0 c
9	67.3 b	69.4 bc	68.3 c	6.0	6.9 bc	6.5 b	3.9 d	3.4 c	3.7 c
7.5	71.7 b	77.3 ab	74.5 b	6.2	5.8 d	6.0 b	5.0 c	6.5 ab	5.7 b
LSD	5.8(**)	10.4(**)	5.7(**)	NS	1.0(**)0.8(**)		0.4(**)	0.9(**)	0.5(**)
(p=0.05)									
Year									
2010	----	74.6		--	--	7	--	--	5
2011	-- --	74.1		--	--	7	--	--	5
LSD(p=0.05) --	--	NS		--	--	NS	--	--	NS
Photoperiod xYear									
LSD(p=0.05)			NS			NS			NS

Least significant differences (LSD) are used to compare treatment means within the column for the data pooled over two growing years 2010 and 2011; while LSD given in italics are used to compare treatment means within the columns for individual year.

NS = Non significant: * $p < 0.05$.

The decreased photoperiod could have contributed to the decreased photosynthetic activity and reduced carbohydrates formation, resulting in lower number of branches per plant. It also helped in stimulation of more lateral bud sprouting. Furthermore, the decrease in photoperiod reduced light to less than required amount for photosynthesis which ultimately would have reduced branches formation. Similar results were recorded by Hlatshwayo and Wahome (2010) in carnation where they recorded an increase in number of lateral Shoots in control and 20% shading.

Total number of suckersplant⁻¹

Higher number of suckers per plant(7.2) were recorded in untreated plants or control, while less number of suckers (3.7) were recorded in plants subjected to 9 hour photoperiod. Photoperiod for 12 hour produced similar results as in 7.5 hour light (Table 1).

The production of suckers may be attributed to the light duration and intensity. Birk (2010); Van de Hoeven (1987) reported that the more sunlight a plant receives the better capacity it has to produce food through photosynthesis. So the plants in control and with 12 hour photoperiod received more light than utilized their photo-assimilates for producing more suckers. On the other hand the plants receiving 10.5 and 9 hour photoperiod could have converted their food to flower buds initiation under less photoperiod. Balaji*et al.* (2010) reported that the plants which experienced congenial long day conditions during vegetative growth resulted in vigorous growth which enabled them to produce more suckers.

Total number of leaves plant⁻¹

Data indicated that the number of leaves in chrysanthemum were significantly affected in response to various photoperiods. Higher number of leaves (54) were recorded in control, while the number of leaves were less (24) in those plants treated with 9 hours photoperiod. Control, photoperiod interval of 12, 10.5, 9 and 7.5 hour were significantly different from each other, while photoperiods of 10.5 and 9 hours influenced the number of leaves per plant in a similar way (Table 2).

Table 2. Effect of photoperiods on number of leaves/plant and leaf area in Chrysanthemum for year 1 (2010) and year 2 (2011).

Photoperiod (hour)	Number of leaves/plant			Leaf area (cm^2)		
	2010	2011	Mean	2010	2011	Mean
Control	62 a	47 a	54 a	145.1 b	158.5 a	151.8 a
12	49 b	42 a	45 b	151.6 ab	143.9 b	147.7 a
10.5	29 cd	24c	26 d	125.8 c	131.0 c	128.4 bc
9	26 d	22 c	24 d	110.3 d	132.5 bc	121.4 c
7.5	35 c	31 b	33 c	160.1 a	107.0 d	133.6 b
LSD(p=0.05)	6.3(**)	5.2(**)	3.9(**)	11.1(**)	11.6(**)	7.7(**)
Year						
2010	--	--	37	--	--	137.2
2011	--	--	36	--	--	136.0
LSD(p=0.05) --	--		NS	--	--	NS
PhotoperiodxYear						
LSD(p=0.05)			NS			NS

Least significant differences (LSD) are used to compare treatment means within the column for the data pooled over two growing years 2010 and 2011; while LSD given in italics are used to compare treatment means within the columns for individual year.

NS = Non significant: * $p < 0.05$.

Higher number of leaves were recorded in uncovered plants that might be due to higher light intensity and photosynthesis, which increased vegetative growth. Duration of light and assimilation by plants enhances photosynthetic activity, which affects other plant characters (Vrsek*et al.*, 2006). Nxumalo and Wahome (2010) counted maximum leaves in uncovered plants in chrysanthemum. Hlatshwayo and Wahome (2010) reported increase in number of leaves under prolonged photoperiods in carnation.

Average leaf area (cm^2)

The leaf area in chrysanthemum was significantly affected by various photoperiods. Higher leaf area (151.8 cm^2) was recorded in control, while it was (121.4 cm^2) in plants treated with 9 hour photoperiod. Control plants and those treated with photoperiod intervals for 12 hours, 10.5 hours, 9 hours and 7.5 hour exhibited significantly different effect on leaf area. The effect of photoperiod on untreated plants and 12 hour duration was similar (Table 2).

The maximum light duration due to high light intensity might have increased the rate of photosynthesis that increased the vegetative growth as well as leaf area in this study. Similar results were reported by Nxumalo and Wahome (2010) in chrysanthemum, where they found greater leaf area in untreated plants as compared to those plants subjected to shading.

Similar findings were reported by Medany*et al.* (2009) in weeping fig (*Ficus benjamina* L) and croton, which confirm the results of this study.

Table 3. Effect of photoperiods on days to flowering, number of flowers/plant and blooming period in Chrysanthemum for year 1 (2010) and year 2 (2011).

Photo-period (hour)	Days to flowering			Number of flowers/plant			Blooming period		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Control	225 a	232 a	228 a	19 a	17 a	18 a	36	33	34 a
12	211 b	219 a	215 b	10 bc	10 b	10 b	29	30	30 ab
10.5	126 d	132 c	129 d	8 c	8 c	8 c	29	25	27 b
9	114 d	127 c	121 d	9 bc	7 cd	8 c	28	26	27 b
7.5	163 c	150 b	156 c	10 b	6 d	8 c	29	29	29 b
LSD (p=0.05)	13.5(**)	13.6(**)	9.2(**)	1.8(**)	1.4(**)	1.1(**)	NS	NS	4.9(*)
Year									
2010	--	--	168	--	--	11	--	--	30
2011	--	--	172	--	--	10	--	--	29
LSD(p=0.05)	--	--	NS	--	--	NS	--	--	NS
PhotoperiodxYear									
LSD(p=0.05)			NS			NS			NS

Least significant differences (LSD) are used to compare treatment means within the column for the data pooled over two growing years 2010 and 2011; while LSD given in italics are used to compare treatment means within the columns for individual year.

NS = Non significant: * $p < 0.05$.

Flowering Characteristics

Number of days to flowering

The number of days to flowering showed significant difference between all treatments influenced by various photoperiods (Table 3), while year wise and interaction of photoperiod and year had non-significant effect on number of days to flowering. Higher number of days to flowering (228 days) were resulted in untreated plants, whereas less number of days (121days) were recorded when plants were exposed to 9 hour photoperiod, and 10.5 hour photoperiod (129days). All the photoperiods except 9 and 10.5 hour were significantly different from each other.

Being a short day plant, chrysanthemum responded to the less light conditions. Untreated and those treated with 12 hour photoperiod, the dark period was far less than required for flower initiation and they could not triggered the stimulus to initiate flowering. That is why control and 12 hour photoperiod took more number of days to flower. On the other hand when photoperiod was shortened further to 7.5 hour, the days to flower again increased to 156 days as 7.5 hour photoperiod provided less light duration than required for flower initiation. It was observed that the time to flowering significantly decreased with decrease in photoperiod. Plants under low irradiance (Less light) took less time to flower whereas days to flower increased significantly in control and under less shade levels. Wieland (1998); Janick (2008) reported that short days are created by covering the plants with a black cloth to initiate flowering. Similar results were reported by Balochet *al.* (2009) who recorded a decrease in days to flowering with increase in shade levels in short day ornamental annuals.

Total number of flowers plant^{-1}

Number of flowers per plantwere significantly affected under the influence of different photoperiod regimes. Number of flowers were significantly higher (18) in control, compared to plants exposed to 9 hours photoperiod (8).Plants exposed to 10.5, 9 and 7.5 hour photoperiods had similar effect(Table 3).

The plants subjected to less photoperiod produced early flowering, while they had less food production due to shading. Hence they could not increase the number of flowers due to less food reserves. Hlatshwayo and wahome, (2010) recorded highest number of flowers in carnations grown without shading. Less number of flowers per plant were reported by Cermeno *et al.* (2001) in chrysanthemum under less light duration. A reduction in number of inflorescence produced in begonia as a result of increased shading intensities has been reported by Jeong *et al.* (2007).

Blooming period (Days)

Blooming period in chrysanthemum flowers indicated significant difference for photoperiods. Significantly longer blooming period (34 days) was recorded in untreated plants compared to 9 hour photoperiod (27 days). Control recorded significant difference with 10.5, 9 and 7.5 hour photoperiod, while 10.5, 9 and 7.5 hour photoperiods were statistically similar in their effect (Table 3).

The blooming period was significantly longer in plants that were not covered with black cloth and was shorter when plants were exposed to shorter photoperiods created artificially in long days. The reduction in blooming period in plants under 10.5 and 9 hour photoperiods might be attributed to the flowering in warm season, due to which drying and desiccation occurred early, while in control and 12 hour photoperiod, the flowers opened in cool environment. That might be the reason, they bloomed for longer period.

Flower Size (cm)

The flower size showed significant difference for different photoperiods. Large flower size (5.3 cm) was recorded in control followed by 12 hour photoperiod (5.2 cm). The smaller flower size (4.8 cm) was recorded in plants treated with 9and 7.5 hour photoperiod (Table 4).

Table 4. Effect of photoperiods on flower size and flower fresh weight in Chrysanthemum for year 1 (2010) and year 2 (2011).

Photoperiod (hour)	Flower size (cm)			Flower fresh weight (g)		
	2010	2011	Mean	2010	2011	Mean
Control	4.9 ab	5.7 a	5.3 a	3.5 ab	3.8 a	3.6 a
12	5.3 a	5.1 b	5.2 ab	3.6 a	3.5 ab	3.6 a
10.5	4.5 b	5.2 ab	4.9 bc	3.1 c	3.4 b	3.3 b
9	5.2 a	4.3 c	4.8 c	3.4 b	3.0 c	3.2 b
7.5	4.9 ab	4.7 bc	4.8 c	3.4 b	3.3 bc	3.3 b
LSD(p=0.05)	0.5(*)	0.56(**)	0.41(*)	0.22(**)	0.29(**)	0.18(**)
Year						
2010	--	--	5.0	--	--	3.4
2011	--	--	5.0	--	--	3.4
LSD(p=0.05) --		--	NS	--	--	NS
Photoperiod xYear						
LSD(p=0.05)			NS			NS

Least significant differences (LSD) are used to compare treatment means within the column for the data pooled over two growing years 2010 and 2011; while LSD given in italics are used to compare treatment means within the columns for individual year.

NS = Non significant: * p < 0.05.

The larger size of flower in control and plants treated with 12 hour photoperiod may be attributed to the improved light and better conversion of food reserves to increase flower size as the plant had enough food to provide it to flower. Higher number of leaves and leaf area also played their role to produce greater size flowers. Strong light has a decisive effect on correct and fast growth of flower buds (Jerzy and Borkowska, 2004). Nxumalo and Wahome (2010) also reported greater flower size in untreated plants.

Flower fresh weight (g)

Flower fresh weight recorded significant difference against various light intervals (Table 4), while the variable was non significantly affected by year and interaction of photoperiod and year. Increased weight (3.6 g) was observed in control and 12 hour photoperiod, while reduced flower fresh weight (3.2 g) was recorded in plants treated with 9 hour photoperiod. Plants treated with 10.5, 9 and 7.5hour photoperiod were statistically at par regarding flower fresh weight (Table 4).

The higher flower fresh weight in control and 12 hour photoperiod might be due to more leaves, larger leaf area and more branches that contributed in the increased fresh flower weight. Similar results have been reported by Scuderi *et al*. (2008) in weeping fig (*Ficus benjumina* L.) and Croton (*Coadiaeum variegatum*L.).

Conclusion

This study has highlighted the importance of photoperiod for off season flowering in chrysanthemum. Application of photoperiod from 9 to 10 hours can help to produce flowers in chrysanthemum earlythan the normal season. This practice can help producers to get flowering atthe time of their own choice.

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