Research Article

Photoperiodic Effect on Vegetative Growth and Flower Quality of Zinnia (*Zinnia elegans* Jacq.)

Safdar A. Wahocho, Tanveer F. Miano*, Noor U.N. Memon and Niaz A. Wahocho

Department of Horticulture, Sindh Agriculture University, Tandojam, Pakistan.

Abstract | The photoperiodic effects on vegetative growth and flower quality of Zinnia (*Zinnia elegans* Jacq.) were examined during 2015 at the Horticulture orchard, Sindh Agriculture University Tandojam in a three replicated RCBD design. The zinnia plants were grown under four photoperiodic treatments which included T_1=Natural photoperiod (Control), T_2=4 hours daylight (8 am -12 noon), T_3=6 hours daylight (8 am – 2 pm) and T_4=8 hours daylight (8 am – 4 pm). The results revealed significant ($P<0.05$) photoperiodic effect on all the growth and quality traits of Zinnia. The Zinnia grown under 8 hours daylight (8 am – 4 pm) with 38.29 cm plant height, 6.61 side branches plant^{-1}, 41.25 leaves plant^{-1}, 39.75 days taken to initiate flower bud, 7.49 cm flower diameter, 5.76 g weight of single flower, 3.27 days taken to open 1st flower, 8.41 flowers plant^{-1}, 23.67 days blooming period and 28 percent leaf chlorophyll content. Similarly, photoperiodic treatment comprised of 6 hours daylight (8 am – 2 pm) produced 30.37 cm plant height, 4.36 side branches plant^{-1}, 23.91 leaves plant^{-1}, 45.66 days taken to initiate flower bud, 5.37 cm flower diameter, 3.98 g weight of single flower, 5.24 days taken to open 1st flower, 6.50 flowers plant^{-1}, 16.33 days blooming period and 25 percent leaf chlorophyll content. It was concluded that growing Zinnia under 8 hours daylight (8 am – 4 pm) was an appropriate photoperiod in relation to number of flowers as well as flower quality.

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Correspondence | Tanveer F. Miano, Department of Horticulture, Sindh Agriculture University, Tandojam, Pakistan; **Email:** drtanveerfmiano@yahoo.in
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Introduction

Zinnia, a summer annual flower, has become so popular due to variant range of colours, belongs to family Compositae. According to 2009 census of Horticultural specialist (NASS) production of cut flower is worth over $400 million annually in the USA (Dar et al., 2002). Zinnia is presently used in containers, patio pots and window boxes. Zinnia is qualitative short day plant and flower is initiated well when given 5 short days having at least 12 hours light period (Kim et al., 2009). Yu et al. (2002) showed that prompt flowering was promoted under warm environmental conditions when grown under greenhouse conditions. Few of herbaceous plants are responsive to short day lengths (Kim et al., 2009). Intensity of light significantly affects the flowering of bedding plants. Blanchard and Runkle (2011) reported that flowering establishment was rapid under warm environment having applied with cloth for shade purpose. Maximum light intensities results in rapid flower establishment as more carbon has been allocated that results in rapid reproductive stage.

Rise in temperature reduce time taken from bud to flower development (Yu et al., 2002); and temperature influences flowering behaviour of many photoperiods sensitive plants (Lokhande et al., 2003). Arabidopsis,

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as well as other qualitative short day plants have been accounted for early flowering (25 days) at short photoperiod of 8 hours (Lokhande et al., 2003). Flower formation is controlled by duration of the day, provided temperatures are in the appropriate range required for growth. Besides light quality and intensity, photoperiod is known to have an adverse effect on growth and development performance of many plants which may directly or indirectly influencing flower development and many other mechanisms of variable characters (Ha et al., 2013). Light duration, light quantity, and quality of sun light have much influence right from the plant growth and development from seed germination up to flower. Photoperiod is one of the detrimental parameters affecting plant growth and flowering behaviour. Recently, lot of considerations has been emphasized on many aesthetic plants under light duration as a factor affecting plants behaviour (Runkle and Heins, 2006). Chemical, biological and physiological metabolism are changed by temperature (Kim et al., 2009) in summer, production of cut flowers especially when temperature exceeds 38°C, the biological processes are adversely affected. Under the conditions of extremely high temperatures, the plant proteins are denatured, affecting these processes and subsequently the flower quality is adversely affected (Ha, 2014). Flowering of all 25 chrysanthemum cultivars was delayed from 4 to 13 days at 16°C under short days (Ploeg et al., 2005). Being an ornamental cut flower plant, Zinnia is relatively sensitive by nature, environmental stress conditions and weeds. Keeping in view the photoperiod effects on flowering in Zinnia, the present research has been conducted to examine the photoperiodic effect on vegetative growth and flower quality of Zinnia.

Materials and Methods

The research was conducted during the year 2015 from March to May where the average natural temperature was about 34.08 °C to examine the photoperiodic effect on vegetative growth and flower quality of Zinnia. The experimental fields of the Orchard, Department of Horticulture, Sindh Agriculture University Tandojam were used for this field study. Seeds of *Zinnia elegans* var. "Purple Prince" were sown directly in the field at the distance of 8 inches within plants and 1 ft between rows (six plants plot^{-1}). After ten days of seed germination, a traditional black cloth system was used to shorten the day length on each plot. The experiment was replicated thrice in a Randomized complete block design (RCBD). Each replication consisted of 06 plants. Four photoperiod treatments were tested. The daylight for treatments were obtained by imposing a blackout with black cloth suspended on a wooden frame. The black cloth was opened and covered daily between 8 a.m. and 4 p.m. Each frame measure 1.0 m x 1.4 m and 1.2 m in height. The treatments included: T_1 = Natural photoperiod (12 hours as control), T_2 = 4 hours daylight (8 am -12 noon), T_3 = 6 hours daylight (8 am – 2 pm), T_4 = 8 hours daylight (8 am – 4 pm). The main plot was divided into 12 sub-plots measuring 1m x 2m (2m^2). Hence, the sub-plots were strictly monitored for development of any weeds so that experimental plants can utilize more nutrients and moisture optimally.

Observations Recorded

Plant Height (cm): It was measured from base to the top of plant with foot scale of each plants from each replication and then average was done.

Side Branches and Leaves plant^{-1}: These parameters were counted visually at flowering stage of the each plant from each replication then, average was taken out.

Days Taken to Initiate Flower Bud: This parameter was done by counting days from sowing time till the appearance of first flower bud on the plant.

Days taken to open 1st flower: This parameter was observed after bud initiation till the bud opened completely as a flower and the days were counted for each plant, then average was worked out.

Flower diameter (cm): Flower diameter (cm) was recorded from each plant through vernier caliper by measuring the Centre half of the flower then value was subjected to the formula;

$$D = {}^{4}/_{3}\, \pi r^2$$

Flowers plant^{-1} and weight of single flower (g): Total number of flower from each plant were visually counted and then average was done for each treatment, while, weight of single flower was recorded by measuring each plant's flower on weighing balance machine.

Chlorophyll content (Spad): This observation was measured through chlorophyll meter as total chlorophyll content from randomly selected leaves by placing meter in the centre of each leaf and value was recorded.

Blooming period (days): Blooming period was recorded from the day of flower opening till it remained in a fresh condition on the plant.

The data were statistically analyzed using Statistics-8.1 computer software. The LSD test was applied to compare the treatments superiority.

Results and Discussion

Plant Height (cm)

The photoperiod effect on plant height of *Zinnia elegans* was assessed and the results are shown in Figure 1. It is assumed from the analysis of variance that the plant height of *Zinnia elegans* was significantly ($P<0.05$) affected by the photoperiod treatments. The photoperiod treatment comprised of 8 hours daylight (8 am – 4 pm) produced zinnia plants of maximum height (38.29 cm), while the zinnias developed under photoperiod treatment comprised of 6 hours daylight (8 am – 2 pm) produced plants of 30.37 cm height. Similarly, the Zinnia grown under photoperiod treatment of 4 hours daylight (8 am -12 noon) produced plants of relatively shorter in height (28.74 cm); while the shortest Zinnia plants (24.27 cm) were recorded in control photoperiod treatment (natural photoperiod). The results clearly suggested that growing Zinnia under 8 hours daylight (8 am – 4 pm) was the best photoperiod treatment; and decreasing daylight resulted in a significant ($P<0.05$) increase in the height of the plants. Although, imposing blackout with black cloth suspended on wooden frame restricted daylight for specific hours, but the plants grew faster when 8 hours daylight was provided from 8 am – 4 pm; while curtailing daylight hours imposed adverse effects on the plants and consequently slowing growth was observed but still better than control conditions.

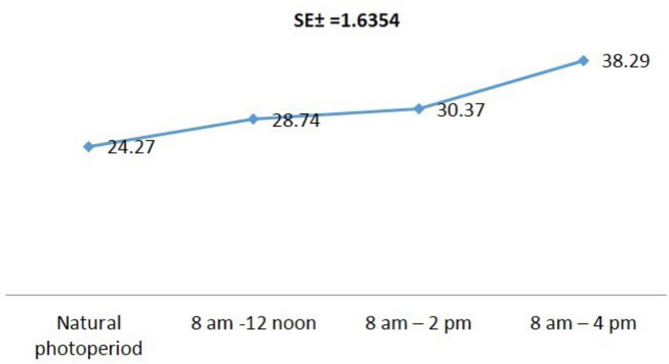

Figure 1: *Plant Height (cm) of zinnia as influenced by different photoperiods*

Daylight, sunshine and temperatures greatly influence the plant vegetative growth and crop production. These results are further supported by many past researchers. Cavins and Dole (2001) reported that 8 hours photoperiod for Zinnia was the most effective to produce optimistic growth and flowering. Adams et al. (2001) reported that photoperiod and light integral are the most important aspects for the ornamental plants which are mainly grown for their proper growth and flowering purpose. Karlsson and Werner (2002) reported that species grown at 20/14°C were 10% to 41% taller than those grown at 16/22°C. Kahar (2008) observed plant height (69.91 cm) at 8 hours daylight with 2 hours incandescent (10PP) for *Chrysanthemum*.

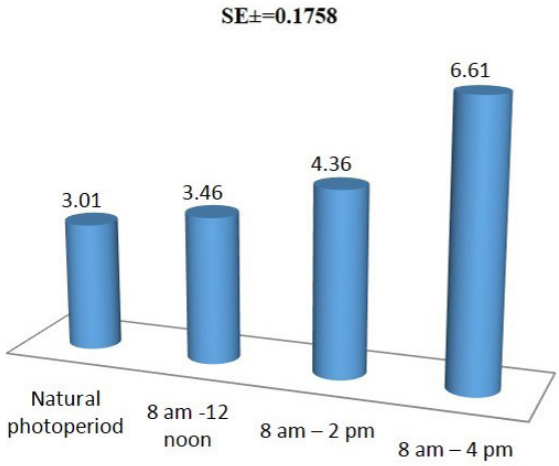

Figure 2: *Side branches plant^{-1} of zinnia as influenced by different photoperiods*

Number of Side Branches Plant^{-1}

The response of *Zinnia elegans* to different photoperiod treatments in relation to the number of side branches plant^{-1} was examined and the results are presented in Figure 2. It was perceived from the analysis of variance that side branches plant^{-1} were significantly ($P<0.05$) influenced by variation in photoperiods. Zinnia plants under photoperiod treatment of 8 hours daylight (8 am – 4 pm) produced maximum number of side branches (6.61), while the Zinnias developed under photoperiod treatment comprised of 6 hours daylight (8 am – 2 pm) produced 4.36 side branches plant^{-1}. Likewise, Zinnia grown under photoperiod treatment of 4 hours daylight (8 am -12 noon) produced relatively lesser number of side branches (3.46); whereas, the minimum number of side branches plant^{-1} were recorded in control treatment, where Zinnia plants were developed under natural photoperiod. It was observed that growing Zinnia under 8 hours daylight (8 am – 4 pm) was the best photoperiod treatment in relation to development of side branches plant^{-1}; and decrease in daylight resulted in a significant (P<0.05) decrease in the number of side branches plant^{-1}. It was observed that imposing blackout with black cloth hanged on wooden frame restricted daylight for particular hours and the plants developed more side branches as compared to natural photoperiod. However, curtailing daylight hours showed adverse effects on the plants vegetative growth and in result sprouting of side branches was checked. Study is in pursuance with Kahar (2008).

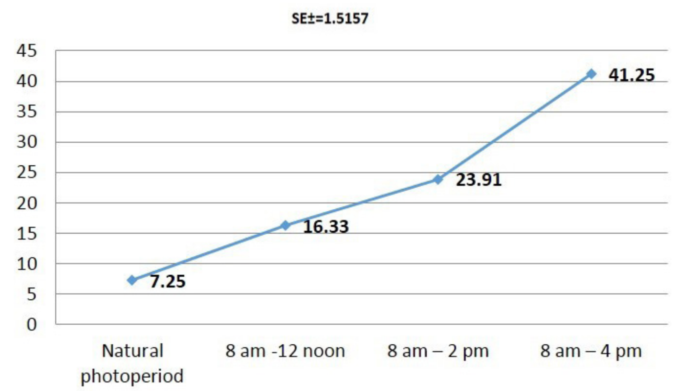

Figure 3: *Number of leaves plant^{-1} of zinnia as influenced by different photoperiods*

Number of Leaves Plant^{-1}

Zinnia elegans growth response to varied photoperiods in terms of leaves plant^{-1} was studied and the data are shown in Figure 3. The analysis of variance showed that the number of leaves plant^{-1} of Zinnia were significantly (P<0.05) affected by variation in photoperiods. Zinnia plants under photoperiod treatment of 8 hours daylight (8 am – 4 pm) produced highest number of leaves (41.25), while Zinnias grown under photoperiod treatment comprised of 6 hours daylight (8 am – 2 pm) produced 23.91 leaves plant^{-1}. Similarly, Zinnia grown under photoperiod treatment of 4 hours daylight (8 am - 12 noon) produced relatively reduced number of leaves (16.33); while the lowest number of leaves plant^{-1} was found in control treatment (7.25), where the Zinnia plants were developed under natural photoperiod. The results showed that growing Zinnia under 8 hours daylight (8 am – 4 pm) was an appropriate photoperiod in relation to development of leaves plant^{-1}; and decrease in daylight resulted in declined number of leaves plant^{-1}. It was further observed that maximum leaves plant^{-1} under 8 hours daylight (8 am – 4 pm) positively associated with the plant height and the number of side branches plant^{-1}. However, blackout with black cloth during 8 am – 12 noon was harmful for the plants, and the plant growth was checked which is reflected from the declined number of leaves plant^{-1} when the blackout period was increased. Adams and Langton (2005) observed that Antirrhiumn cultivars under long days produced early flowering (41.9 days) with a minimum number of leaves below the inflorescence (8.2) as compared to short days, which triggered late flowering (57.3 days) and produced the maximum number of leaves (18.2).

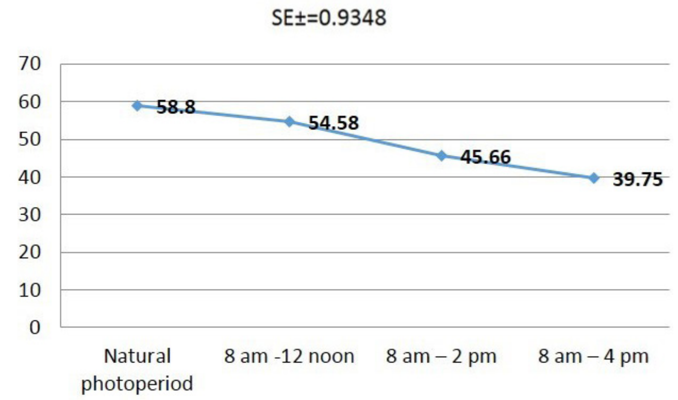

Figure 4: *Days to initiate flower bud of zinnia as influenced by different photoperiods*

Days to Initiate Flower Bud

Zinnia grown under different photoperiods to examine daylight duration effect on the number of days taken by the plants to initiate flower bud; the results to this effect are given in Figure 4. The analysis of variance described significant effect of different photoperiods (P<0.05) on the number of days taken to initiate flower bud. Zinnia plants grown under photoperiod treatment comprised of 8 hours daylight (8 am – 4 pm) had less days to initiate flower bud (39.75), while the Zinnias developed under photoperiod of 6 hours daylight (8 am – 2 pm) took 45.66 days to initiate flower bud. Similarly, Zinnia grown under photoperiod of 4 hours daylight (8 am - 12 noon) took more days to initiate flower bud (54.58); while the maximum number of days to initiate flower bud were recorded in control treatment (58.80), where Zinnia plants were developed under natural photoperiod. The number of days taken to initiate flower bud was inversely proportional to increasing daylight; and under 8 hours daylight (8 am – 4 pm) Zinnia plants showed earliness to initiate flower bud and with decrease in daylight hours resulted in delayed initiation of flower bud. Erwin and Warner (2002) reported that buds took less time for Celosia and Zinnia under warmer temperatures and longer day lengths. *C. bipinnatus* 'Sonata White', and *T. tenuifolia* 'Tangerine Gem' were grown under a non-photo-inductive long day environment [9-h photoperiod plus night-interruption (2 µmol m^{-2} s^{-1} provided by incandescent lamps from 2200-0200 HR)], before being transferred to a photo-inductive short day environment (9-h photoperiod) 0, 5, 10, 15, 20, or 25 d after the first true leaf pair unfolded, *C. bipinnatus* increased the number of short days increased flower bud number.

Flower Diameter (cm)

The photoperiod effects on the flower diameter of Zinnia was explored and the result has been presented in Figure 5. The analysis illustrated that the flower diameter of *Zinnia elegans* was significantly (P<0.05) affected by the photoperiod treatments. The photoperiod of 8 hours daylight (8 am – 4 pm) produced Zinnia flowers of maximum diameter (7.49 cm), while the Zinnias developed under photoperiod of 6 hours daylight (8 am – 2 pm) produced flowers of 5.37 cm diameter. Zinnia grown under control photoperiod produced flowers of relatively shorter diameter (4.72 cm); while Zinnia flowers were of minimum diameter (4.39 cm) when grown under photoperiod of 4 hours daylight (8 am -12 noon). Although, imposing blackout with black cloth suspended on wooden frame restricted daylight for specific hours, but the plants produced bigger flowers when 8 hours daylight was provided from 8 am – 4 pm; while curtailing daylight hours showed adverse impact on the plants and consequently produced smaller flowers. These results are in coincide with Karlsson and Werner (2002) and Yu et al. (2002) who noted 7.13 cm flower diameter under 8-9 h of day length.

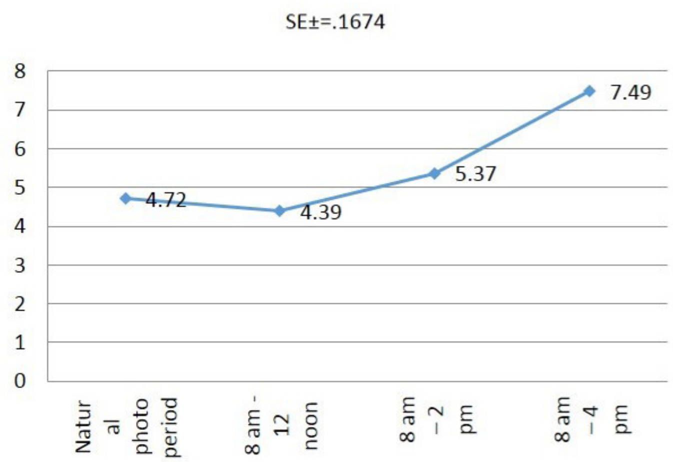

Figure 5: *Flower diameter (cm) of zinnia as influenced by different photoperiods*

Weight of Single Flower (g)

The effect of different photoperiods on weight of single flower in Zinnia was examined and the results to this effect are presented in Figure 6. The analysis described significant effect of different photoperiods on the weight of single flower (P<0.05). Zinnia plants developed under photoperiod of 8 hours daylight (8 am – 4 pm) produced heaviest flowers (5.76 g), while the Zinnias grown under photoperiod of 6 hours daylight (8 am – 2 pm) produced flowers of 3.98 g weight on average. Similarly, Zinnia grown under photoperiod of 4 hours daylight (8 am - 12 noon) produced average flower weight of 3.27 g; while the lowest weight of single flower on average was recorded in control treatment (58.80), where the Zinnia plants were developed under natural photoperiod. This higher weight of single flower under 8 hours daylight (8 am – 4 pm) was mainly associated with the increased flower diameter. The results also suggested that increasing daylight up to 8 hours daylight (8 am – 4 pm) produced healthier Zinnia plants and produced healthy flowers. Hence, for achieving healthy Zinnia flowering, 8 hours daylight (8 am – 4 pm) may be the most effective photoperiod treatment. Ploeg et al. (2005) suggested 9 hours photoperiod for the ornamental flowering plants at 20°C and the days from bud to harvest were less for Zinnia under warmer temperatures and longer day lengths that produced heavier flowers (6.39 g). Baloch et al. (2010) notified increased flowering (5.43) and weight (5.77 g) at 8 hours d^{-1}.

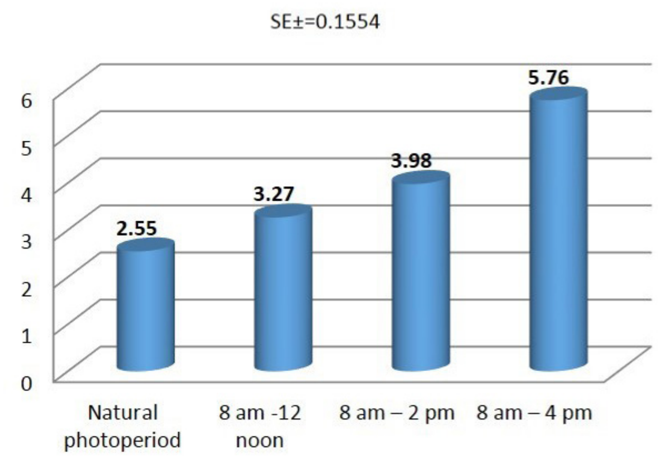

Figure 6: *Weight of single flower (g) of zinnia as influenced by different photoperiods*

Days to Open First Flower

The results to this effect are given in Figure 7. The analysis of data indicated significant effect of different photoperiods (P<0.05) on the days taken to open first flower. Zinnia plants grown under photoperiod of 8 hours daylight (8 am – 4 pm) took minimum days to open first flower (3.27), while the zinnias developed under photoperiod treatment comprised of 6 hours daylight (8 am – 2 pm) took 5.24 days to open first flower. Similarly, the zinnia grown under photoperiod treatment of 4 hours daylight (8 am - 12 noon) took many days to open first flower (5.75); while the maximum days to open first flower were recorded in control treatment (6.98), where the zinnia plants were developed under natural photoperiod. The days to open first flower was inversely proportional to increasing daylight; and under 8 hours daylight (8 am – 4 pm) the zinnia plants showed earliness in the first flower development and with decrease in daylight hours development of first flower was delayed. Karlsson and Werner (2002) grown ornamental plants at 16°C-20°C in combination with short day 8 hours photoperiod treatment and reported that time to flower at 20°C varied from 73 to 87 days with additional light exposure resulting in faster flowering. Most of plants have a photoreceptor protein, such as phytochrome or cryptochrome that sense seasonal changes in day length, and act as promoter to flower. Photoperiodic response to flower induction, initiation and development and growth habit of plant species are temporarily directed annually with night length as reported by Mer and Attri (2015).

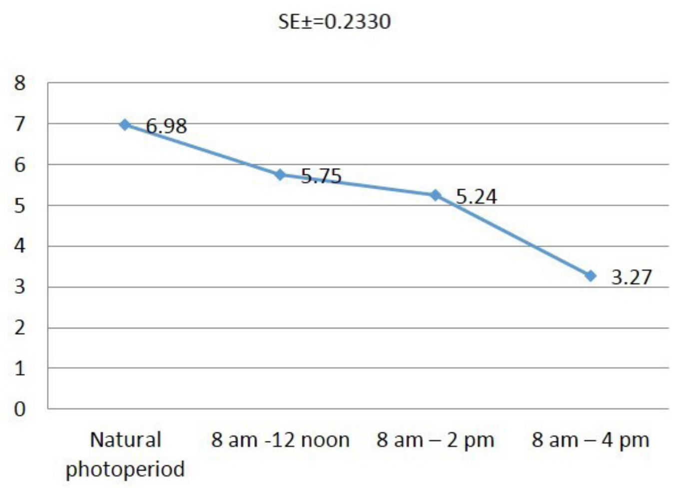

Figure 7: *Number of days taken to open first flower of zinnia as influenced by different photoperiods*

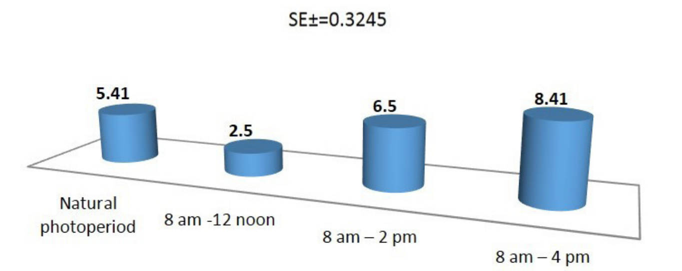

Figure 8: *Flowers plant^{-1} of zinnia as influenced by different photoperiods*

Flowers Plant^{-1}

Zinnia elegans response to varied photoperiods in terms of flowers plant^{-1} was studied and the results are shown in Figure 8. It was identified that flowers plant^{-1} of zinnia were significantly ($P<0.05$) affected by photoperiods variation. The zinnia plants under photoperiod treatment of 8 hours daylight (8 am – 4 pm) produced highest number of flowers (8.41), while the zinnias grown under photoperiod treatment comprised of 6 hours daylight (8 am – 2 pm) produced 6.50 flowers plant^{-1}. Similarly, the zinnia grown under control treatment where the zinnia plants were developed under natural photoperiod produced 5.41 flowers plant^{-1}, while the photoperiod treatment of 4 hours daylight (8 am - 12 noon) produced lowest number of flowers (2.50) plant^{-1}. This higher number of flower plant^{-1} under 8 hours daylight (8 am – 4 pm) was mainly associated with the increased plant height, side branches and leaves plant^{-1}, as these parameters improved, the flowers plant^{-1} were increased simultaneously. Lokhande et al. (2003) experimented on Crowea 'White Star' and found that it produced maximum flowers up to 100 when grown under 11°C in combination with high light exposure (700 μmol m-2 s-1), while 81% of plants were kept at 21°C with same light treatment due to which these plants remained vegetative. Further, Lokhande et al. (2003) reported that *Arabidopsis thaliana* flowered within 31 days at 22°C while flower formation was delayed until 63 days when the temperature was reduced to 14°C. The results suggest that temperature affects both time and rate of flower development. Yu et al. (2002) found that *Zinnia* flowered under photoperiod NI02 (Night interruption 02:00–06:00 HR). Karlsson and Werner (2002) reported that when ornamental plants at 16°C or 20^{0}C were grown with short day (SD, 8 hours) or long day (LD, 16 hours) response, further they found that quicker flowering were found at 16°C (increased from 56 to 64 days).

Blooming Period (days)

The results to this effect are presented in Figure 9, which showed significant effect of different photoperiods ($P<0.05$) on the blooming period. The zinnia plants grown under photoperiod treatment comprised of 8 hours daylight (8 am – 4 pm) showed highest blooming period (23.67 days), while the zinnias developed under photoperiod treatment comprised of 6 hours daylight (8 am – 2 pm) resulted in 16.33 days blooming period. Similarly, the blooming period was 15.08 days in zinnia grown under control treatment where the plants were developed under natural photoperiod. However, the lowest blooming period of 6.98 days was observed in zinnia plants developed under 4 hour daylight (8 am -12 noon). It was observed that growing zinnia under 8 hours daylight (8 am – 4 pm) was an appropriate photoperiod in relation to prolonged blooming period; and decrease in daylight resulted in declined blooming period. It was further noted that under 4 hour daylight (8 am – 12 noon) the blooming period of zinnia was severely affected. This indicated that blackout during day time was harmful for the zinnia as far as the blooming period is concerned. Unlike photoperiod during flower initiation, the longest shelf life (13 days) was found at 8PP as suggested by Kahar (2008), the 2 h incandescent at the end of 8 h daylight period caused synchronization of flowering within a plant. Curry and Ervin (2010) concluded that when day length increased from 9 h to 13 h, the total flower numbers decreased from 45 flowers to 13 flowers *Kalanchoe uniflora* (a short day plant). Jiang et al. (2010) reported improvement in flower quality with increase in photoperiod.

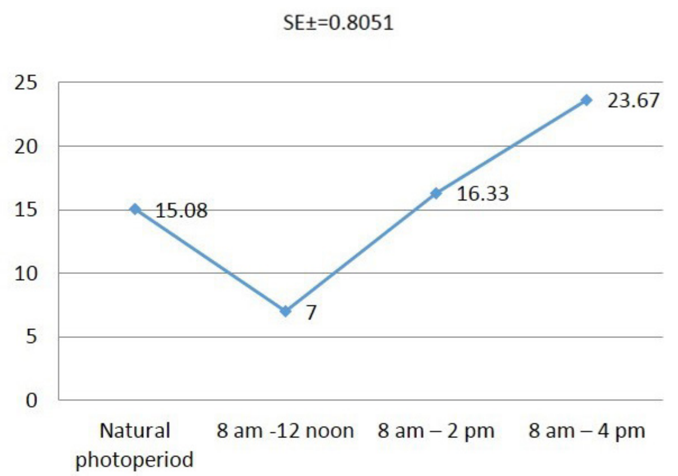

Figure 9: *Blooming period of zinnia as influenced by different photoperiods*

Leaf Chlorophyll Content (%)

Chlorophyll content in zinnia leaves was determined in response to different photoperiods of which the results are presented in Figure 10. Results illustrated that the leaf chlorophyll content in *Zinnia elegans* was significantly (P<0.05) affected by the photoperiod treatments. The leaf chlorophyll content was markedly higher (28%) in plants grown under photoperiod treatment comprised of 8 hours daylight (8 am – 4 pm), while the leaf chlorophyll content was 26% in zinnias developed under control (natural photoperiod); while the leaf chlorophyll content was 25% and 21 percent in zinnias grown under photoperiod treatments comprised of 6 hours daylight (8 am – 2 pm) and 4 hours daylight (8 am -12 noon), respectively. It was observed that increasing daylight up to 8 hours daylight (8 am – 4 pm) resulted in a significant (P<0.05) increase in the leaf chlorophyll content over control; but 6 hours daylight (8 am – 2 pm) and 4 hours daylight (8 am -12 noon) photoperiod did not result leaf chlorophyll content more than the control. Hence, growing zinnia under 8 hours daylight (8 am – 4 pm) proved to be most effective photoperiod treatment with 35.17°C and reduction in daylight would be harmful for leaf chlorophyll content in zinnia. The magnitude of the delay increased as the duration of the extension lighting increased (Table 1). The leaves increased their green matter quantity by LD (16 h) treatment, and constituted a second mechanism that increased dry weight too (Adams and Langton, 2005). Lokhande et al. (2003) reported that the temperature and light affected the chlorophyll content of leaves.

Table 1: *Average temperature (°C) recorded during study*

	March	April	May	Average
T1= Control	32.34	33.56	36.34	34.08
T2- 8-12	32.82	31.61	34.25	32.89
T3- 8-2	33.71	33.29	35.75	34.25
T4- 8-4	34.53	34.18	36.81	35.17
Average	**33.68**	**33.02**	**35.60**	**34.59**

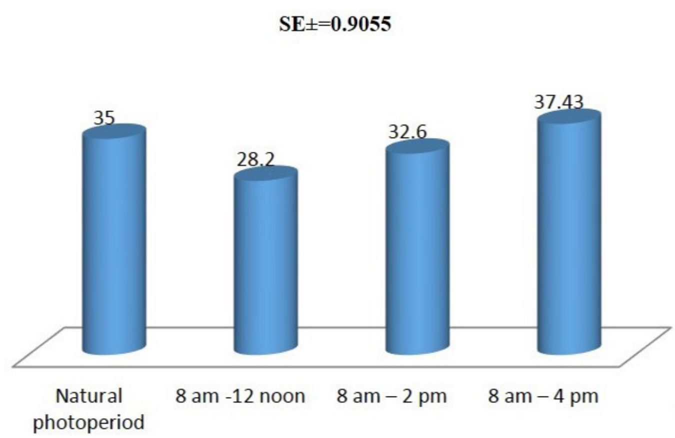

Figure 10: *Chlorophyll content in leaves of Zinnia as influenced by different photoperiods*

Conclusion

From this study, it can be concluded that growing zinnia under 8 hours daylight (8 am – 4 pm) was an appropriate photoperiod for the growth of Zinnia.

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Conflict of Interests

It is confirmed that this paper has not been submitted or published elsewhere.

Authors' Contribution

The author S.A. Wahocho has observed and collected data, Dr. N.N. Memon and Dr. N.A. Wahocho for data analysis and manuscript writing.

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