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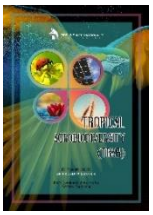

RESEARCH ARTICLE

EFFECTS OF PHOTOPERIOD ON GROWTH AND FLOWERING OF CHRYSANTHEMUM (*Chrysanthemum morifolium Ramate.*) CULTIVAR UNDER PROTECTED CONDITION AT CHANAULI, CHITWAN

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ABSTRACT

Photoperiod plays a crucial role in regulating the growth and flowering behavior of chrysanthemum (*Chrysanthemum morifolium* Ramat.), a short-day and economically important ornamental crop. A study was conducted at Chanauli, Chitwan, Nepal, during 2018/2019 to examine the effect of photoperiod and variety on the morphological, floral, and yield attributes of chrysanthemum under protected conditions. Six varieties-Zembla Cream, Arctic Queen White, Green Button, Kathleen Dark Red, Zembla Sunny, and Pink Chandramallika were tested under two photoperiod treatments: light and no-light. The experiment followed a factorial Completely Randomized Design (CRD) with four replications. Results revealed that the vegetative and reproductive traits were significantly influenced by both variety and photoperiod. Overall, plant height, stem diameter, plant spread, flower size, and flower yield declined with the absence of supplemental light. Zembla Cream showed superior performance across most parameters, particularly under extended light, including higher flower diameter (8.14 cm), flowering duration (12 days), and yield (48.3 t/ha). Green Button performed well vegetatively under light conditions, while Kathleen Dark Red showed the highest SPAD reading. Interaction effects between variety and photoperiod were mostly non-significant. Based on the findings, Zembla Cream, Arctic Queen, and Green Button emerged as promising varieties for off-season production using artificial lighting in protected cultivation. However, further research is needed to validate these results across broader environmental conditions.

KEYWORDS

Chrysanthemum, Artificial light, Flowering time, Varietal response, Pocket farming

1. INTRODUCTION

Floriculture is an emerging sector of agriculture. There is fast expanding trade of floriculture. The global trade in ornamental horticulture was U$$ 11.9 billion in 2005 with annual growth rate at 10-12% (FAN/AEC, 2007). The area of floriculture is expanding day by day due to education, urbanization, awareness hotel and tourism. The dramatic growth in contribution of floriculture sector and subsequently to the economy was backed by the positive responses of some of the stakeholders including private sector institutions and business associations such as FAN (Floriculture Association Nepal) with the support of AEC of FNCCI (FAN, 2007).

The floriculture has been started since 1950 in Nepal. There are 675 flower farms/nurseries and 141 hectors of land for flower cultivation in 38 districts in Nepal. In 2015, the values of flower products are: seasonal flowers produced Rs. 216.8 million, ornamental plant Rs. 381.50 million, cut flower Rs. 204.50 million, land scape and gardening flower products Rs. 170.40 million, and other flower products Rs. 67.00 million (FAN, 2016). The floriculture has been becoming one of the prominent sectors in Nepalese economy contributing 0.05% of the total national Gross Domestic Product (GDP). Although, the annual growth rate of flowers production is 24%, the import value was 0.4 million in 2014/015 (FAN, 2016).

There is higher potentiality for expanding of floriculture and enhancing flower products because of diversified agro-ecological settings in the country. Despite being flourishing with greater possibility; this sector is still at very earlier stage of establishment. This sector has been facing several constraints such as inputs, technology development and transfer, credit access, and flower market, and etc. In developing countries, smallholder farmers are frequently handicapped by ineffective extension services and poor access to agriculture credit that lead the farmers to be inefficient (Akobundu et al., 2004; Fletschner, 2008). Such constraints hindered the floriculture and led to higher quantity of imports of the flower products estimated to be Rs. 40 million in 2014 (FAN, 2016). Kathmandu, Lalitpur, Bhaktapur, Chitwan, Makwanpur and Kavrepalanchowk are the commercial districts of Nepal for the production of cut flowers (Gauchan et al., 2009).

Floriculture industry in Nepal started in more organized way after the establishment of Floriculture Association Nepal (FAN) in 1992. Floriculture has been emerging as viable agro-business in Nepal with great potential for export. However, institutional efforts to promote the floriculture research and development are still very limited (Joshi and Pun, 2006).

It is native of china known as 'Autum Queen' or ' Queen of the East' is a commercially exploited for its attractive coloured flowers (Koley and Sarkar, 2013). It occupies a prominent place in ornamental horticulture and mainly grown as cut flower, flowering pot plant and loose flower for making garlands and bracelets for worship (Van Der Ploeg and Heuvelink 2006; Bohra and Kumar, 2014). In Nepal research on chrysanthemum was

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done on 2016 B.S after the establishment of botanical garden. There are greater than 15000 varieties were developed by Japan whereas more than 60,000 varieties were listed by the National Chrysanthemum Society of Britain (FAN, 2015).

Chitwan is a potential area of chrysanthemum flower production. Despite the suitable climate, soil and environment conditions and opportunities, the quantitative and qualitative production of this crop has been constrained. One of the major reasons is that there is a lack of technical information regarding the crop management practices with respect to growth, flowering and yield increment. The demand for chrysanthemum loose flower during festivals, social and religious ceremonies is high. Hence production of chrysanthemum should be increased to meet the growing demand of Nepalese people. In Nepal, no works have been done on year round production of chrysanthemum by manipulating photoperiod. Thus there is necessity to conduct series of research for determining the appropriate photoperiod and appropriate varieties for maximizing the yield and quality of the chrysanthemum flower.

In chrysanthemum, photoperiod and variety are the major factor for quality flower production. Chrysanthemum is a photosensitive plant with critical day length of 13 ½ h (Post 1931, Furuta, 1954). It produces flowers by exposing the plants to the short day length than the critical photoperiodic requirement. The flowering could even be controlled when the long-night is interrupted by a short exposure of light (night break) especially red (R) light. In the open cultivation, the flowering of chrysanthemum is confined only to limited period from October to December, which cannot meet the growing demand of chrysanthemum flowers among the people and, thus, limits the economic return to the grower. It is therefore, always desirable to control short-day effect for controlling the vegetative growth or extend the flowering duration in chrysanthemum for off-season availability of flowers. The flowering in chrysanthemum is either promoted by subjecting the plants to dark periods of more than 12 h or inhibited by night interruption by light exposure for few hours with continuous or intermittent low intensity light (cyclic light) using fluorescent or incandescent lamps (Cathey and Borthwick 1964).

Therefore, keeping in view the effect of photoperiod on different variety of chrysanthemum for prolonging the flowering, this research has been conducted to study the effect of photoperiod on growth and flowering of chrysanthemum.

2. Materials and Methodology

2.1 Experimental Design

The research was conducted at ABLOOM Horticulture farm Chanauli which is 13km south-west from Bharatpur, Chitwan, Nepal. This site is located at 27 ^{0} 37' North latitude and 84 ^{0} 25' East longitude with the elevation of 256 masl. The study was carried out from 2nd of October, 2017 to 16th of May, 2018.

The Metrorological data recorded from Natioanl Maize Researh Program (NMRP), Rampur, has been presented in Figure 1.

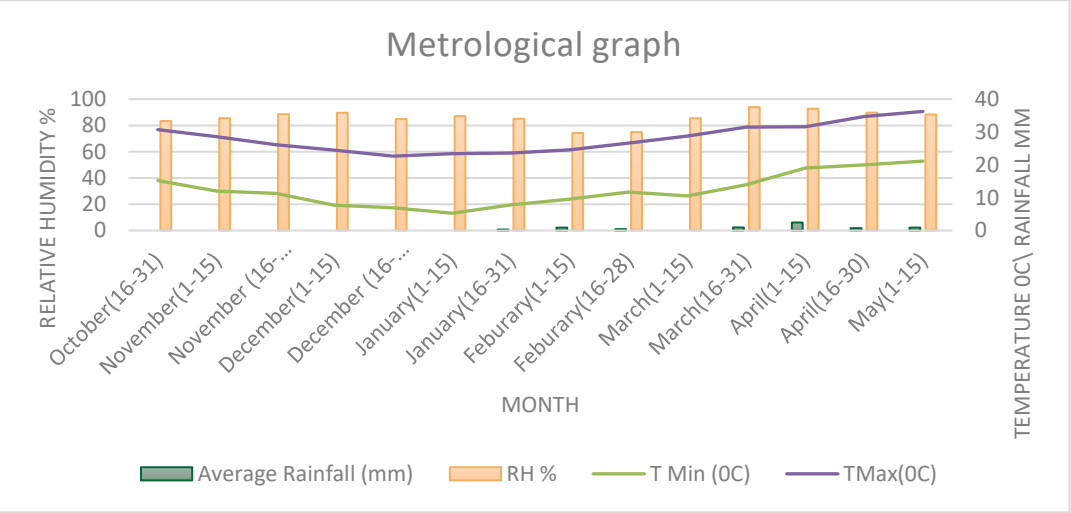

Figure 1: Meterological information during the experimentation period recorded at National Maize Research Program (NMRP), Chitwan, Nepal from October to May, 2018

The average maximum temperature was in May (36.26 ^{0}C) and Minimum temperature was in January (5.27 ^{0}C). Relative humidity was highest (93.93 %) in March and Lowest (74.22 %) in February while Maximum rainfall (6.11mm) was recorded in March and minimum rainfall (0.73mm) was recorded in October during the growth period of chrysanthemum.

The metrological data inside the plastic house was recorded during the research period at chanauli, chitwan from December to April, 2018

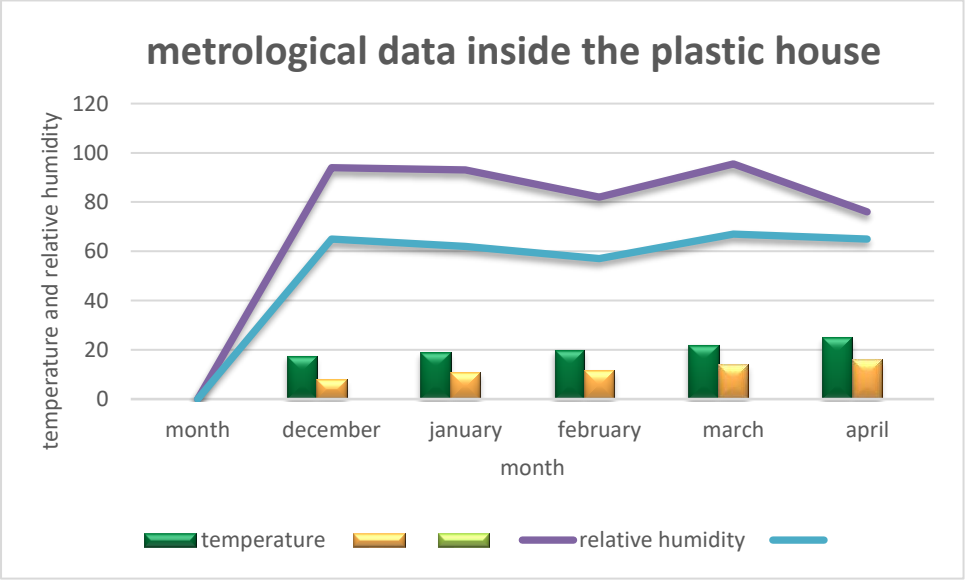

Figure 2: Metrological information during experimentation period recorded at chanauli, chitwan, Nepal from December to April, 2018

The average maximum temperature was in April (25 ^{0}C) and minimum temperature was in December (8^{0}C) whereas relative humidity was highest in March (95.5%) while lowest in February (57%)

2.1.1 Experimental and Treatment details

The experiment was conducted in Complete Block Design (CBD) with 12 treatments and each treatment was replicated 4 times. 48 plots were designed having area of 0.56 m^2 (0.7m * 0.8m) and each containing 56 plants.

The research was conducted in two factorials completely randomized design. Six different varieties of chrysanthemum were considered as one factor while condition of light as second factor.

Factor A: Varieties

Variety 1 (Pink chandramallika)

Variety 2 (Arctic Queen White)

Variety 3 (Zembla Sunny)

Variety 4 (Kathleen Dark Red)

Variety 5 (Green Button)

Variety 6 (Zembla Cream)

Factor B: Light

Light

No- light

2.1.2 Treatment combination

Treatment	Designation
T1	Arctic queen white X Light
T2	Pink chandramallika X Light
T3	Kathleen Dark Red X Light
T4	Green Button X Light
T5	Zembla Cream X Light
T6	Zembla Sunny X Light
T7	Pink chandramallika X No light
T8	Arctic queen white X No light
T9	Kathleen Dark Red X No light
T_{10}	Green Button X No light
T_{11}	Zembla Cream X No light
T_{12}	Zembla Sunny X No light

2.1.3 Layout of experimental field

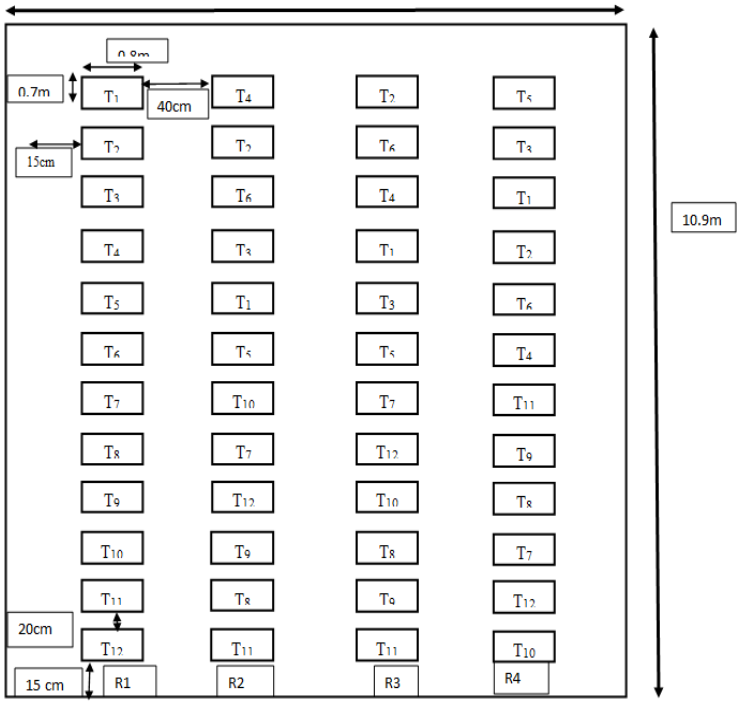

Figure 3: Layout of experimental field

2.2 Seedling preparation and transplantation

The cuttings of chrysanthemum were raised on nursery bed on December 17, 2018. 10-15 cm of pencil thick one-year old stem having 3 nodes were planted in the medium of organic manure and fertile soil containing nursery bed and covered during the night hours by using the plastic film and open during the day hours. The cuttings were ready after one month which sprouted about 3-4 leaves and roots. They were transplanted to the main field after its preparation without its roots disturbance.

The land was well prepared, two deep ploughing was done by using the power tiller. Crop residues, stubbles, weed plants etc were incorporated into the soil. Different plots were made ready according to design of experiment. The transplanting of cutting on commercial field was done on January 13, 2019 into the plot with the spacing of 10cm x 10cm row to row and plant to plant respectively. Altogether there were 56 cuttings per plot.

2.3 Intercultural Operation

The recommended dose of nitrogen, phosphorus and potassium was 20:20:10 gram/m^2 was applied with well-decomposed FYM (farm yard manure). DAP was given at the rate of 50 gram/m^2 and after third week of transplanting the cutting, the following nutrient management was done by applying two times per week.

Fertilizers	Amount (gram/m^2)
Potassium Nitrate (KNO_3)	4
Calcium Ammonium Nitrate (CAN)	3
Ammonium Nitrate (NH_4NO_3)	3
Magnesium Sulphate ($MgSO_4$)	3

The irrigation was given by mixing fertilizer on water at two weeks' interval. Trench was made between the replication to facilitate the irrigation to the plant. The weeding was done at 15 days' interval after 4th week of transplanting of the cutting. Staking was done by maintaining distance of 3 to 4 inch between the plants with the plastic rope.

The harvesting of flower was done after the gain of required size and where there was 50% flowering occur per plant. The harvesting was done by the means of scissors at morning time.

Installation of Artificial Light

The LED light was installed into the commercial field with in the treatment. The LED light of 12 Watt was used at the height of five and half feet above the ground by maintaining the distance of 1.5 meter with in the replication. The supplementary light was gave for 4 weeks after 15 days of transplanting the cuttings. The light intensity of LED light was 4.85 lux.

2.4 Data Collection and Analysis

Among 56 plants in the plot, 8 plants of the central region were randomly selected for the observation and data on different parameters was collected at 15 days interval by repeating 4 times. Vegetative observation was done by measuring length of main stem (cm) to the tip of plant and canopy covered by plant (cm) with measuring tape while spad reading was measured by chlorophyll meter on leaves of top, middle and lower part and calculating average.

For observation of reproductive parameters, we recorded days to first flowering opening and to 50% of flowering after transplanting, counting total number of flowers and weighing average of fresh weight of harvested first 10 flower and dry weight of those flower after putting on oven at 55^0 C for 72 hours. The yield of the flower per hectare was recorded by calculating the number of spray per m^2.

The Analysis of variance (ANOVA), MS-Excel 2010 and the R program 3.3 version was used for entry, processing, computation and analysis of all data as a whole. All data was analysed using Analysis of Variance (ANOVA) and the "R" –statistical package. Treatment differences were compared by using mean, CV percentage, LSD at 5%. The ANOVA model for factorial CRD experimental design is given below:

Source	SS	df	MS	F
Main effects				
A	SSA	a-1	MSA= SSA/(a-1)	MSA/MSE
B	SSB	b-1	MSB= SSB/(b-1)	MSB/MSE
Interaction				
AB	SSAB	(a-1) (b-1)	MAB=SSAB/(a-1) (b-1)	MSAB/MSE
Error	SSE	ab (n-1)		

3. Result and Discussion

3.1 Plant height (cm)

Table 1: Plant height influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019

Treatments	15DAT	30DAT	45DAT	60DAT
Variety				
V1(pink chandramallika)	10.57 b	21.07 b	59.32 a	59.82 a
V2(Arctic queen white)	11.69 a	21.1 b	60.01 a	60.52 a
V3(zembla sunny)	11.86 a	22.32 b	61.09 a	61.63 a
V4 (Kathleen dark red)	7.77 c	12.73 c	41.95 c	42.5 c
V5(Green button)	12.38 a	24.43 a	57.22 ab	57.76 ab
V6(Zembla cream)	12.24 a	21.69 b	54.37 b	54.72 b
$LSD_{0.05}$	0.877	1.752	3.665	3.635
SEM(±)	0.306	0.611	1.278	1.297
P-value	<0.001**	<.001**	<.001**	<.001**
Photoperiod				
L1	13.02a	19.36 b	64.79 a	65.31 a
L2	9.15 b	21.76 a	46.53 b	47 b
LSD0.05	0.506	1.012	2.116	2.099
SEM(±)	0.176	0.353	0.738	0.732
P-value	<0.001**	<.001**	<.001**	<.001**
Interaction				
Pink chandramallika x light	11.95 c	19.76 c	69.03 a	69.54 a
Pink chandramallika x no light	9.2 e	22.38 ab	49.61 c	50.11 c
Arctic queen white x light	13.6 b	18.85 c	70.34 a	70.88 a
Arctic queen white x no light	9.77 de	23.35 ab	49.69 c	50.16 c
Zembla sunny x light	13.13 bc	21.15 bc	71.72 a	72.24 a
Zembla sunny x no light	10.6 d	23.5 ab	50.47 c	51.02 c
Kathleen dark red x light	9.19 e	12.71 d	50.78 c	51.37 c

Table 2 (cont): Plant height influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019				
Kathleen dark red x no light	6.34 f	12.75 d	33.13 d	33.63 d
Green button x light	15.09 a	24.87 a	66.12 a	66.77 a
Green button x no light	9.67 de	24 a	48.31 c	48.75 c
Zembla cream x light	15.13 a	18.82 c	60.75 b	61.09 b
Zembla cream x no light	9.34 de	24.57 a	47.98 c	48.35 c
p- value	<0.001**	0.004*	0.237 ns	0.227 ns
Grand mean	11.08	20.56	55.66	56.16
SEM(±)	0.432	0.864	1.807	1.793
LSD(0.05)	1.240	1.240	2.478	5.141
CV%	7.8	8.4	6.5	6.4

Treatments means followed by the common letter (s) within column are non-significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, SEm = Standard error of mean and CV = Coefficient of variation

There was significant difference among varieties for plant height was observed at 15, 30, 45 and 60 days after transplanting. Green Button variety generally showed maximum height at earlier stages of 15, 30 and 45 DAT while Zembla Sunny showed best height at 60 DAT. At every stage Kathleen Dark Red variety consistently had the minimum plant height (table). The variation in an plant height is due to the genetic variation in morphological characteristics among the different spray cultivar which is reported by (Jarial and Dhiman, 2015)

Photoperiod also significantly influenced plant height at all growth stages, with plants under light conditions consistently exhibiting greater heights of 13.02cm, 21.76cm, 64.79cm and 65.31cm at 15, 30, 45 and 60 DAT respectively, while minimum plant height was recorded in no light condition (table) The study revealed that, plants under 6-hour additional light exhibited the maximum plant height (76.0 cm), followed by exposure to 4-hour additional light of 73.9 cm (Singh et al., 2006). and similar result was observed by (Dierck et al., 2017).

Interaction between variety and photoperiod was significant only at 15 and 30 DAT. Zembla Cream and Green Button performed best under light conditions with 15.13cm/23.5cm and 15.09cm/24.87cm respectively at 15/30 DAT (table no. 6). However, there is increase in plant height of all varieties in light condition as result of enhanced photosynthetic activities under artificial long day conditions accompanied by accumulation of carbohydrate and nitrogen in the treated plant (Datta and Seemanthini, 2000).

3.2 Spad reading

Table 8: Spad reading influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019				
Treatments	**15DAT**	**30DAT**	**45DAT**	**60DAT**
Variety				
V1 (Pink chandramallika)	15.62 ab	24.84 ab	25.3 ab	26.13 a
V2 (Arctic queen white)	15.55 ab	24.11 b	24.29 abc	24.23 ab
V3 (Zembla sunny)	13.99 b	22.19 c	25.57 ab	25.99 ab
V4 (Kathleen dark red)	17.71 a	26.31 a	21.19 c	22.21 b
V5 (Green button)	9.34 c	21.88 c	26.87 a	27.72 a
V6 (Zemba cream)	13.12 b	23.08 bc	22.59 bc	24.07 ab
$LSD_{0.05}$	3.092	1.781	3.238	3.531
SEM(±)	1.078	0.621	1.129	1.231
P-value	<.001**	<.001**	0.012*	0.049*
Photoperiod				
L1 (light)	18.54 a	31.75 a	30.51 a	30.88 a
L2 (No light)	9.90 b	15.72 b	18.10 b	19.24 b
$LSD_{0.05}$	1.785	<1.028	1.869	2.039
SEM(±)	0.622	0.358	0.652	0.711
P-value	<.001**	<.001 **	<.001**	<.001**
Interaction				
Pink chandramallika x light	22.07 ab	34.69 a	33.31 ab	33.2 ab
Pink chandramallika x no light	9.18 e	15 d	17.29 e	19.06 f
Arctic queen white x light	22.29 ab	33.81 a	31.04 b	30.16 bc
Arctic queen white x no light	8.82 e	14.42 d	17.54 e	18.3 f
Zembla sunny x light	17.95 bc	29.5 b	33.07 ab	33.44 ab
Zembla sunny x no light	10.04 de	14.88 d	18.08 e	18.54 f
Kathleen dark red x light	23.19 a	33.86 a	23.28 cd	24.64 de
Kathleen dark red x no light	12.24 de	18.76 c	19.11 de	19.79 ef
Green button x light	11 de	29.36 b	36.57 a	37.51 a
Green button x no light	7.67 e	14.39 d	17.17 e	17.93 f
Zembla cream x light	14.76 cd	29.3 b	25.76 c	26.33 cd
Zembla cream x no light	11.49 de	16.86 cd	19.43 de	21.82 def

Table 8 (cont): Spad reading influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019				
p- value	0.003*	<.001**	<.001**	<.001**
Grand mean	14.22	23.74	24.30	25.06
SEM(±)	1.525	0.878	1.596	1.741
LSD(0.05)	4.373	2.519	4.579	4.993
CV%	21.4	7.4	13.1	13.9

Treatments means followed by the common letter (s) within column are non-significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, SEm = Standard error of mean and CV = Coefficient of variation

There was significant difference among varieties for spad reading was observed at 15, 30, 45 and 60 days after transplanting. At 15 and 30 DAT Kathleen Dark Red generally exhibited highest chlorophyll content at with reading of 17.71 and 26.31 while Green Button showed minimum chlorophyll content of 9.34 and 21.88 respectively. But at 45 and 60 DAT, Green Button exhibited highest spad reading with 26.87 and 27.72 and Kathleen Dark Red showed minimum chlorophyll content with 21.19 and 22.21 respectively. It suggests that Green Button has strong late-stage chlorophyll content development.

There was significant difference among photoperiod for spad reading was observed at 15, 30, 45 and 60 days after transplanting. Plants grown under light conditions consistently displayed higher SPAD readings compared to those in no-light conditions. This clearly indicates that light exposure promotes increased chlorophyll content in the leaves.

Interaction of variety and photoperiod significantly affected spad reading presented in Table. Maximum reading was recorded in Kathleen Dark Red at 15 and 30 DAT with reading of 23.19 and 33.86 respectively being statistically at par with other varieties also. Similary at 45 and 60 DAT, Green Button performed best under light conditions with observation of 36.57 and 37.51 respectively. As reported that LED lighting resulted in higher chlorophyll content in the leaves of the plant (Klamkowski et al., 2012). In the case of French marigold darker leaves with a higher value of the index of leaves greenness were obtained in plants cultivated under the blue and red light, the lightest, on the other hand (Academy, 2015).

It is evident from above results that varieties Kathleen dark red and Green button performed best in light condition however the increase rate of spad reading of remaining varieties indicate that light condition was more favorable than No light condition though they cannot perform well in both photoperiod condition.

3.3 Plant spread

Table 9: Plant spread influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019				
Treatments	**15DAT**	**30DAT**	**45DAT**	**60DAT**
Variety				
V1 (Pink chandramallika)	9.26 cd	12.06 cd	13.55 b	14.04 bc
V2 (Arctic queen white)	10.08 bc	12.55 bc	13.92 b	14.38 b
V3 (Zembla sunny)	10.65 b	13.17 ab	14.73 a	15.2 a
V4 (Kathleen dark red)	10.07 bc	12.73 bc	13.83 b	14.25 b
V5 (Green button)	8.93 d	11.53 d	12.85 c	13.37 c
V6 (Zemba cream)	11.52 a	13.62 a	15.07 a	15.47 a
$LSD_{0.05}$	0.828	0.793	0.704	0.6992
SEM(±)	0.289	0.277	0.245	0.2438
P-value	<.001**	<.001**	<.001**	<.001**
Photoperiod				
L1 (light)	10.47a	13.70a	14.67a	15.065a
L2 (No light)	9.70 b	11.52b	13.31b	13.83b
$LSD_{0.05}$	0.478	0.458	0.406	0.4037
SEM(±)	0.167	0.160	0.142	0.1408
P-value	0.002*	<.001**	<.001**	<.001**
Interaction				
Pink chandramallika x light	10.01 cdef	13.38 bc	14.29 b	14.73 b
Pink chandramallika x no light	8.51 g	10.75 f	12.81 d	13.35 d
Arctic queen white x light	10.47 abcd	13.44 bc	14.98 ab	15.32 ab
Arctic queen white x no light	9.69 defg	11.67 def	12.86 d	13.43 d
Zembla sunny x light	11.07 abc	14.62 a	15.46 a	15.86 a
Zembla sunny x no light	10.22 bcde	11.72 def	14.01 bc	14.54 bc
Kathleen dark red x light	10.97 abcd	14.06 ab	14.62 ab	14.99 ab
Kathleen dark red x no light	9.16 efg	11.4 def	13.03 cd	13.52 cd
Green button x light	8.88 fg	12.03 de	13.13 cd	13.62 cd
Green button x no light	8.98 efg	11.02 ef	12.57 d	13.12 d
Zembla cream x light	11.43 ab	14.67 a	15.54 a	15.86 a
Zembla cream x no light	11.62 a	12.57 cd	14.59 ab	15.08 ab
p- value	0.105ns	0.178ns	0.326ns	0.397ns
Grand mean	10.08	12.61	13.99	14.42
SEM(±)	0.408	0.391	0.491	0.3448
LSD(0.05)	1.171	1.122	0.995	0.9888
CV%	8.1	6.2	5	4.8

Treatments means followed by the common letter (s) within column are non-significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, SEm = Standard error of mean and CV = Coefficient of variation

There was significant difference among varieties for plant spread was observed at 15, 30, 45 and 60 days after transplanting. At 15 DAT, maximum plant spread was recorded in variety zembla cream (11.52cm) followed by zembla sunny (10.65cm) being statistically at par with Kathleen dark red (10.07cm) and Arctic queen white (10.08cm) whereas minimum plant spread was recorded in variety Green button (8.93cm) being statistically at par with pink chandramallika (9.26cm). At 30 DAT, maximum plant spread was recorded in variety zembla cream (13.62cm) being statistically at par with variety zembla sunny (13.17cm) followed by Arctic queen white (12.55cm) and kathleen dark red (12.73cm) whereas minimum plant spread was recorded in variety Green button (11.53cm) being statistically at par with pink chandramallika (12.06cm). At 45 DAT, maximum plant spread was recorded in variety Zembla cream (15.07cm) being statistically at par with zembla sunny (14.73cm) followed by Arctic queen white (13.92cm) and pink chandramallika (13.55cm) whereas minimum plant spread was recorded in variety Green button (12.85cm). At 60 DAT, maximum plant spread was recorded in variety zembla cream (15.47cm) being statistically at par with the Zembla sunny (15.2) followed by Arctic queen white (14.38cm), Kathleen dark red (14.25cm) and pink chandramallika (14.04cm) whereas minimum plant spread was recorded in variety Green button (13.37cm). Rakesh et al. (2005) reported that spread of chrysanthemum was maximum in Sonali Tara (38.36) while minimum was found in Pandhri Rewadi (31.79 cm).

There was significant difference among photoperiod for plant spread was observed at 15, 30, 45 and 60 days after transplanting. At 15 DAT, maximum plant spread was recorded in under light condition (10.47cm) whereas minimum spad reading was recorded in No light condition (9.70cm). At 30 DAT maximum plant spread was recorded under light condition (13.70cm) whereas minimum plant spread was recorded in No light condition (11.52cm). At 45 DAT maximum plant spread was recorded under light condition (14.67cm) whereas minimum plant spread was recorded in No light condition (13.31cm). At 60 DAT maximum plant spread was recorded under light condition (15.06cm) whereas minimum plant spread was recorded in No light condition (13.83cm). Increase in plant spread might be due to production of increased number of branches. Similar findings have also been reported by Mishra (2006).

Interaction of variety and photoperiod Not significantly affected plant spread presented in Table 9. It is evident from above results that varieties zembla cream and Zembla sunny performed best in light condition however the increase rate of plant canopy of remaining varieties indicate that light condition was more favourable than No light condition though they cannot perform well in both photoperiod condition.

3.4 Days to first flowering

Table 11: Days to first flowering influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019

Treatments	Days to 1st flowering
Variety	
V1 (Pink chandramallika)	85.48 b
V2 (Arctic queen white)	82.12 c
V3 (Zembla sunny)	83.56 bc
V4 (Kathleen dark red)	90.03 a
V5 (Green button)	75.61 d
V6 (Zembla cream)	81.54 c
SEM(±)	0.908
LSD0.05	2.604
P-value	<.001**
photoperiod	
L1	94.36 a
L2	71.76 b
SEM(±)	0.524
LSD0.05	1.503
P-value	<.001**
Interaction	
Pink chandramallika x light	98.56 a
Pink chandramallika x no light	72.41 e
Arctic queen white x light	93.03 bc
Arctic queen white x no light	71.22 e
Zembla sunny x light	95.5 ab
Zembla sunny x no light	71.62 e
Kathleen dark red x light	97.37 a
Kathleen dark red x no light	82.69 d
Green button x light	89.37 c
Green button x no light	61.84 f
Zembla cream x light	92.31 bc
Zembla cream x no light	70.78 e
p- value	<.001**
Grand mean	83.06
SEM(±)	1.284
LSD(0.05)	3.682
CV%	3.1

Treatments means followed by the common letter (s) within column are non-significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, SEm = Standard error of mean and CV = Coefficient of variation

There was significant relationship among varieties, photoperiod and their interaction for Days to first flowering was observed. Maximum days to first flowering was observed in variety Kathleen dark red (90.03) whereas least number of days to firsst flowering was observed in variety Green Button (75.61). Kazaz et al (2010) reported that long day (LD) conditions delayed days to flower by 42 days as compared to short day (SD) conditions in *Chrysanthemum morifolium* (cvs. 'Yellow Reagan' and 'White Reagan'). Similarly, maximum Days to first flowering was recorded in under light condition (94.36) whereas minimum days to first flowering was recorded in No light condition (71.76). Maximum days to first flowering was obtained under light condtition in variety pink chandramallika (98.56) being statistically at par with other varieties whereas least number of days to first flowering was recorded in variety Green button (61.84) under no light condition.

It is evident from above results that varieties pink chandramallika and Kathleen dark red performed best in light condition however the increase rate of days to first bud flowering remaining varieties indicate that light condition was more favourable than No light condition.

3.5 Days to 50% flowering

Table 12: Days to 50% flowering influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019

Treatments	Days to 50% flowering
Variety	
V1 (Pink chandramallika)	87.72 a
V2 (Arctic queen white)	84.33 a
V3 (Zembla sunny)	85.88 a
V4 (Kathleen dark red)	92.67 a
V5 (Green button)	78.63 a
V6 (Zembla cream)	84.13 a
SEM(±)	4.36
LSD0.05	12.51
P-value	0.364ns
photoperiod	
L1	95.5a
L2	75.7b
SEM(±)	2.52
LSD0.05	7.22
P-value	<.001**
Interaction	
Pink chandramallika x light	98.56 a
Pink chandramallika x no light	76.88 bcd
Arctic queen white x light	94.03 abc
Arctic queen white x no light	74.62 cd
Zembla sunny x light	96.41 ab
Zembla sunny x no light	75.35 cd
Kathleen dark red x light	97.94 a
Kathleen dark red x no light	87.41 abc
Green button x light	91.85 abc
Green button x no light	65.41 d
Zembla cream x light	93.94 abc
Zembla cream x no light	74.31 cd
p- value	0.875ns
Grand mean	85.6
SEM(±)	6.17
LSD(0.05)	17.69
CV%	14.4

Treatments means followed by the common letter (s) within column are non-significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, SEm = Standard error of mean and CV = Coefficient of variation

There was significant difference among photoperiod for days to 50 % flowering was observed while Non-significant relationship among varieties their interaction. Maximum Days to 50 % flowering was recorded in under light condition (95.5) whereas minimum days to 50 % flowering was recorded in No light condition (75.7). It is evident from above results that varieties pink chandramallika and Kathleen dark red performed best in light condition however the increase rate of days to first bud flowering remaining varieties indicate that light condition was more favourable than No light condition though they doesnot perform well in both photoperiod condition which is found similar in report by (Siddiqua et al., 2017).

3.6 Number of flower per plant

Table 14: Number of flower per plant influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019

Treatments	Number of flower per plant
Variety	

Table 14 (cont): Number of flower per plant influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019	
V1 (Pink chandramallika)	7.624 a
V2 (Arctic queen white)	6.771 b
V3 (Zembla sunny)	6.396 bc
V4 (Kathleen dark red)	5.875 c
V5 (Green button)	7.416 a
V6 (Zembla cream)	6.396 bcd
SEM(±)	0.1759
LSD0.05	0.5046
P-value	<.001**
photoperiod	
L1	6.805a
L2	6.688a
SEM(±)	0.1016
LSD0.05	0.2913
P-value	0.417 ns
Interaction	
Pink chandramallika x light	7.875 a
Pink chandramallika x no light	7.373 ab
Arctic queen white x light	6.832 bc
Arctic queen white x no light	6.71 bcd
Zembla sunny x light	6.167 cde
Zembla sunny x no light	6.625 bcde
Kathleen dark red x light	5.917 de
Kathleen dark red x no light	5.833 e
Green button x light	7.622 a
Green button x no light	7.21 ab
Zembla cream x light	6.417 cde
Zembla cream x no light	6.375 cde
p- value	0.476ns
Grand mean	6.746
SEM(±)	0.2488
LSD(0.05)	0.7136
CV%	7.4

Treatments means followed by the common letter (s) within column are non-significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, SEm = Standard error of mean and CV = Coefficient of variation

There was significant relationship among varieties for number of flower was observed while non-significant result was observed among photoperiod and their interaction. Maximum number of flower was observed in variety pink chandramallika (7.62) being statistically at par with other varieties also whereas least was found in Kathleen dark red (5.87). (Kumar, 2011) reported that the maximum number of flower per plant was observed under variety Decorative white (42) and Golden incurved (42) while the minimum number of flower per plant was recorded under the variety Pompon Rosy Pink (18).

3.7 Fresh weight (Gram)

Table 16: fresh weight influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019	
Treatments	**fresh weight (Gram)**
Variety	
V1 (Pink chandramallika)	3.729 cd
V2 (Arctic queen white)	3.845 c
V3 (Zembla sunny)	3.509 d
V4 (Kathleen dark red)	5.487 b
V5 (Green button)	2.791 e
V6 (Zembla cream)	7.531 a
SEM(±)	0.1076
LSD0.05	0.3085
P-value	<.001**
Photoperiod	
L1	4.698a

Table 16 (cont): fresh weight influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019	
L2	4.266b
SEM(±)	0.0621
LSD0.05	0.1781
P-value	<.001**
Interaction	
Pink chandramallika x light	3.97 e
Pink chandramallika x no light	3.487 eg
Arctic queen white x light	3.967 ef
Arctic queen white x no light	3.722 efg
Zembla sunny x light	3.562 efg
Zembla sunny x no light	3.455 g
Kathleen dark red x light	5.967 c
Kathleen dark red x no light	5.008 d
Green button x light	2.775 h
Green button x no light	2.807 h
Zembla cream x light	7.947 a
Zembla cream x no light	7.115 b
p- value	0.012*
Grand mean	4.482
SEM(±)	0.1521
LSD(0.05)	0.4362
CV%	6.8

Treatments means followed by the common letter (s) within column are non-significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, SEm = Standard error of mean and CV = Coefficient of variation

There was significant relationship among varieties, photoperiod and interaction between them for fresh weight was observed. Maximum fresh weight was observed in variety Zembla cream (7.53gram) whereas least was found in green button (2.79gram). similar findings were found in different spray cultivar of chrysanthemum by (Katwate et al., 1992). Maximum fresh weight was observed under light condition (4.69gram) whereas least was observed under No light condition (4.26gram). As reported that flower fresh weight was maximum at control condition (3.6 gram) while least (3.2 gram) was found in 9 hours of treatment (Sajid, Amin, Khan, Rehman, and Hussain, 2016). Maximum fresh weight was observed under the light condition in variety Zembla cream (7.94gram) whereas minimum fresh weight was observed under No light condition in variety pink chandramallika (3.48gram) being statistically at par with Arctic queen white (3.72gram) and Zembla sunny (3.45gram).

It is evident from above results that varieties Zembla cream and Kathleen dark red performed best in light condition however the increase in fresh weight of remaining varieties indicate that light condition was more favourable than No light condition though they do not perform well in both photoperiodic condition.As reported that maximum fresh weight (36.99 gram) was found in Red-blue LED light treatment while minimum fresh weight (6.24 gram) was found in blue LED light treatment (Sabzalian et al., 2015). As reported that low light also retarded floret initiation and perianth formation and increase the variability of flower development(Cockshull and Huge., 1971). This may be due to transfer of reserved carbohydrate in the leaves to the flower or it may be due to varietal characterstics.

3.8 Dry weight (gram)

Table 17: Dry weight influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019	
Treatments	**Dry weight (Gram)**
Variety	
V1 (Pink chandramallika)	0.3075 d
V2 (Arctic queen white)	0.3488 c
V3 (Zembla sunny)	0.34 cd
V4 (Kathleen dark red)	0.6525 b
V5 (Green button)	0.3313 cd
V6 (Zembla cream)	0.8812 a
SEM(±)	0.0112
LSD0.05	0.0319
P-value	<.001**
Photoperiod	
L1	0.4871a
L2	0.4667b
SEM(±)	0.00642
LSD0.05	0.01842
P-value	0.031*
Interaction	

Table 17 (cont): Dry weight influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019	
Pink chandramallika x light	0.295 f
Pink chandramallika x no light	0.32 ef
Arctic queen white x light	0.3575 e
Arctic queen white x no light	0.34 ef
Zembla sunny x light	0.35 e
Zembla sunny x no light	0.33 ef
Kathleen dark red x light	0.625 d
Kathleen dark red x no light	0.68 c
Green button x light	0.3325 ef
Green button x no light	0.33 ef
Zembla cream x light	0.9625 a
Zembla cream x no light	0.8 b
p- value	<.001**
Grand mean	0.4769
SEM(±)	0.01573
LSD(0.05)	0.04511
CV%	6.6

Treatments means followed by the common letter (s) within column are non-significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, SEm = Standard error of mean and CV = Coefficient of variation

There was significant relationship among varieties, photoperiod and interaction between them for dry weight was observed. Maximum dry weight was observed in variety Zembla cream (0.88gram) whereas least was found in pink chandramallika (0.30gram). Maximum dry weight was observed under light condition (0.48gram) whereas least was observed under No light condition (0.46gram). The result is in accordance with light treatment on dry weight of flower were maximum found in Day Supplement (14.6gram) reported by (Moon 1971) Maximum dry weight was observed under the light condition in variety Zembla cream (0.96gram) followed by variety Kathleen dark red (0.62gram) and Arctic queen white (0.35gram) whereas minimum dry weight was observed under No light condition in variety pink chandramallika (0.29gram) being statistically at par with Arctic queen white (0.35gram) and Zembla sunny (0.33gram). The photoperiod effect on dry weight directly related with the fresh weight of flower, the flower having greater fresh weight may have greater dry weight (Dahab, 1967)

3.9 Flower yield (tons/ha)

Table 18: Flower yield influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019	
Treatments	**flower yield (tons/ha)**
Variety	
V1 (Pink chandramallika)	27.85 c
V2 (Arctic queen white)	25.86 c
V3 (Zembla sunny)	22.48 d
V4 (Kathleen dark red)	32.15 b
V5 (Green button)	20.76 d
V6 (Zembla cream)	48.3 a
SEM(±)	0.739
LSD0.05	2.118
P-value	<.001**
Photoperiod	
L1	29.80a
L2	29.33a
SEM(±)	0.426
LSD0.05	1.223
P-value	0.445ns
Interaction	
Pink chandramallika x light	27.98 c
Pink chandramallika x no light	27.73 c
Arctic queen white x light	25.93 cd
Arctic queen white x no light	25.78 cd
Zembla sunny x light	22.86 de
Zembla sunny x no light	22.1 e
Kathleen dark red x light	32.5 b
Kathleen dark red x no light	31.8 b
Green button x light	20.95 e

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Table 18 (cont): Flower yield influenced by photoperiod on different variety of chrysanthemum in chitwan, Nepal on 2018/2019	
Green button x no light	20.57 e
Zembla cream x light	48.58 a
Zembla cream x no light	48.02 a
p- value	1.000ns
Grand mean	29.57
SEM(±)	1.045
LSD(0.05)	2.996
CV%	7.1

Treatments means followed by the common letter (s) within column are non-significantly different among each other based on DMRT at 5% level of significance. LSD = Least significant difference, SEm = Standard error of mean and CV = Coefficient of variation

There was significant relationship among varieties for flower yield was observed. Maximum flower yield was observed in variety Zembla cream (48.3ton/ha) followed by variety Kathleen dark red (32.15ton/ha), Arctic queen white (25.86ton/ha) being statistically at par with pink chandramallika (27.85ton/ha) whereas least was found in zembla sunny (22.48tons/ha) being statistically at par with Green button (20.76tons/ha).

While there was Non-significant relationship among photoperiod and its interaction with the variety for flower yield was observed. Similar result was found in variety 'Indira' which produce highest number of spray per hectare (1223.67 thousand) reported by (Phule and Vidyapeeth, 1996).

Zembla Cream and Kathleen Dark Red performed best under light conditions, indicating its positive influence on flower yield. Overall yield variation was attributed to varietal traits and light quality (Kumar, 2011).

4. Conclusion

The experiment brought some important information on effect of photoperiod and variety on morphological, floral, and yield parameters of chrysanthemum.

For vegetative and flowering character variety Zembla cream and Arctic queen white were superior to other varieties. In light condition variety Green Button variety was more preferable for vegetative characters. Similarly, for flowering characters, variety Zembla cream followed by Zembla sunny both in photoperiod condition. Flowering period is also maximum in variety Zembla cream under light condition in Nepal. Considering delay flowering with the use of light treatment variety zembla cream, Kathleen dark red and Green button was more preferable while variety pink chandramallika poor performance as compare to other variety.

Thus we can conclude that among the varieties under study, Zembla cream, Arctic queen and Green button can successfully be cultivated in Chitwan by changing the day length with the use of artificial light under protected condition which can fulfil the demand of flower in lean season. However still more studies are required to assess the varietal performance and it would be premature to recommend suitable variety for given photoperiod condition.

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