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PLANT GROWTH ANALYSIS OF GREENHOUSE CHRYSANTHEMUM ON INTERRUPTED PHOTOPERIODIC REGIME

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Abstract- Chrysanthemum is the significant cut flower in the Indian market. It is a short day plant where flowering occurs when existence of long nights and short days. A greenhouse study was conducted to find out the physiological response of chrysanthemum due to interrupted photoperiodic regime at a Private garden Salem Green Plants Limited, Yercaud, Salem District in Tamil Nadu. The study was carried through in a Factorial Randomized Block Design (FRBD) with 21 treatment combinations and three replications. The first factor (L) comprised of seven long day regimes (3h, 4h & 5h extended light along with 6h, 8h & 10 h interrupted LD regime) including control and three levels of SD regimes (13 h, 14 h & 15 h dark) constituted the second factor (S). The results revealed that 10 min of continuous light in every 30 min cycle for 8 h (4 h extended light) along with 13 h short day regime (L_6S_1) had improved the plant growth parameters like crop growth rate (CGR), net assimilation rate (NAR), relative growth rate (RGR) and IAA oxidase activity at the critical stages of the crop (66.34, 186.31 and 166.07 µg of un-oxidized auxin g^{-1} h^{-1}). This is followed by L_3S_1 (4 hours of extended light continuously) which registered the lowest level of auxin content at vegetative stage and higher amount at bud appearance and flowering stage respectively. Total carbohydrate content was highest (L_6S_1) at bud appearance stage of about 3.35 % followed by plant receiving interrupted lighting for 8 hours duration. The improvement in physiological parameters influenced the number of quality grade flowers (73.90 stems/m^2) and cut stem yield (78.60 stems/m^2).

Keywords- Greenhouse chrysanthemum, interrupted light regime, plant growth analysis, crop growth rate, net assimilation rate, IAA oxidase activity, flower yield

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Introduction

Floriculture is emerging as a potent and profitable agro-industry in several developed countries, since last few decades. Flowers are the vibrant element in decorative flowering plants and they look awesome where we live [15]. Chrysanthemum (Family: *Asteraceae*) is the third most important cut flower in the international market after rose and tulip. India has a huge potential to grow good quality chrysanthemums. The climatic conditions prevailing in the Eastern Ghats of Tamil Nadu (Yercaud) is the most favourable zone for growing chrysanthemums under protected conditions. These are definitive short day plants where the flowering is controlled by the variant length of light hours. To achieve continuous supply of flowers in a year, programming the maintenance of long and short day duration during the plant growth is inevitable. The invention of photoperiodism in chrysanthemum facilitated the fruitful production of chrysanthemum flower all-round the year [1,15]. Continuous lighting for achieving LD conditions assumed to charge additional cost on electricity. From an economic point of view, interrupted lighting should only be used when it has a significant influence on growth and flowering. To study growth parameters at different light regimes, plant growth analysis can be used. Analysis of physiological parameters is one such approach to investigate the plant growth and function amply. Under such circumstances, it is important to know how the level of interrupted light influences the growth when compared to continuous lighting. In order to study the physiological responses of chrysanthemum on interrupted photoperiodic regimes, a greenhouse study was conducted with the above mentioned objectives.

Materials and Methods

The experiment was executed at a naturally ventilated polyhouse at private garden, M/s Salem Green Plants Ltd. Yercaud (Latitude 11° 04" to 11° 05" N, Longitude 78° 05" to 78° 23" E and Altitude 1500 m MSL), Salem district of Tamil Nadu to study the physiological responses of greenhouse chrysanthemum under interrupted photoperiodic regime during winter season. The experiment was laid out in a Factorial Randomized Block design (FRBD) with twenty one treatment combinations and three replications. The treatment combinations are given in the Tabular column below.

	Treatment details (Factor 1- Long day regimes)		(Factor 2 – Short day regimes)
L_1	Control	S_1	13 h continuous dark
L_2	9 hours Natural day light + 3 h extended light	S_2	14 h continuous dark
L_3	9 hours Natural day light + 4h extended light	S_3	15 h continuous dark
L_4	9 hours Natural day light + 5 h extended light		
L_5	10 min of continuous light in every 30 min cycle for 6 h (3 h extended light)		
L_6	10 min of continuous light in every 30 min cycle for 8 h (4 h extended light)		
L_7	10 min of continuous light in every 30 min cycle for 10 h (5 h extended light)		

The spray variety Punch was rooted in mist chamber and 15 days after rooting, the seedlings were planted in the main field at a spacing of 12.5 x 10 cm which accommodates 80 plants per sq.m. Plants were fertilized twice a week with water soluble fertilizers and spray of micronutrient mixture @ 0.2% during the experiment. Long day conditions were given for first 3 weeks after planting and so the plants remained vegetative. The interrupted light regimes were achieved with the help timer fixed to the lighting systems. The light was "ON" continuously for 10 minutes in every 30 minutes of cycle for about 6, 8 and 10 hours respectively. The short day conditions were achieved by closing growing greenhouse area with the black polythene film according to the treatment schedule. The packages of practices were followed as per the crop production guide. Five plants in each treatment combinations were randomly tagged in each of the plot (treatment and replication wise) and observed for plant growth parameters at critical stages of the crop. All data were analyzed statistically [10]. The flowering time coincides with the winter season.

Results and Discussion

Crop Growth Rate

The physiological parameters, which observed showed a significant treatment differences. A rapid crop growth rate has been also found to be an important trait for improving yield of flowers [7]. Crop growth rate (CGR) had positive association with LAI [14]. The LAI (Leaf Area Index) and CGR are the prime most authority which decides the total dry matter production and subsequent utilization of assimilates for sink development. The interrupted and continuous lighting for 6 h & 8 h and 3h & 4 h in winter significantly influenced the crop growth rate from bud appearance stage to flowering stage (16.91 and 27.20) than vegetative stage to bud appearance stage (17.39 and 26.19). As CGR is a linear function of intercepted irradiance, it implies that at higher CGR, larger will be the light interception and more will be the LAI, which in turn leads to higher dry matter accumulation [Fig-1]. This is line with the findings of [6] in chrysanthemum. The plants which receive interrupted lighting registered the highest CGR at bud appearance to flowering stage. The lowest CGR was recorded in the control (L_1S_1) where plants are grown in normal conditions.

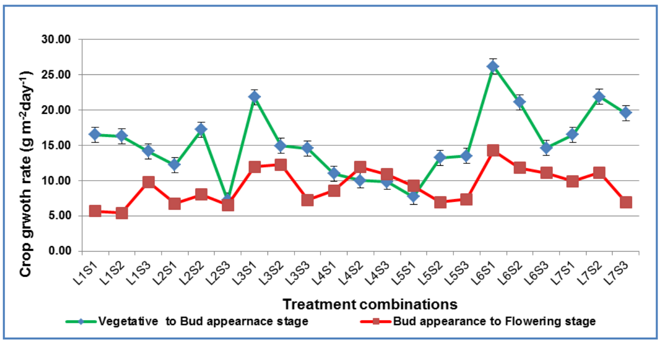

Fig-1 Effect of photoperiod by continuous vs interrupted lighting on crop growth rate (g $m^{-2}day^{-1}$) during winter season

Net Assimilation Rate

Net assimilation rate indicates the assimilatory capacity of the leaves for biomass production in unit time. It represents the difference between carbon gained in photosynthesis and carbon used in respiration. NAR exhibited a peak at flowering stage, suggesting the efficiency of plants for the production of as many number of flowers as possible. The decline in NAR at later stages might be due to increased leaf production of the crop plants, which resulted in reduction of photosynthesis by mutual shading of leaves. The Net Assimilation Rate (NAR) is significantly increased by the photoperiodic levels. A considerable reduction in NAR was also observed due to light stress at different stages of growth [Table-1]. This is also in line with the findings of [5]. The least NAR was observed in the control (L_1S_1) and LD regime of continuous light for 3 hours (L_2S_1).

Table-1 *Effect of photoperiod on Net Assimilation Rate (mg cm^{-2} day^{-1}) of spray chrysanthemum during winter season*

Treatment	Net Assimilation Rate (mg cm^{-2} day^{-1})							
	Vegetative stage to Bud appearance stage				Bud appearance stage to Flowering stage			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
L_1	0.85	0.83	0.64	**0.77**	0.45	0.45	0.84	**0.58**
L_2	1.18	1.04	1.22	**1.15**	0.57	0.67	0.57	**0.60**
L_3	1.92	1.82	1.28	**1.67**	1.04	1.23	0.62	**0.96**
L_4	1.71	1.42	1.29	**1.48**	0.73	1.06	0.93	**0.91**
L_5	0.61	1.10	0.93	**0.88**	0.78	0.57	0.61	**0.65**
L_6	2.26	1.89	1.25	**1.80**	1.05	1.03	0.96	**1.01**
L_7	1.43	1.35	1.04	**1.27**	0.87	0.94	0.60	**0.80**
Mean	**1.42**	**1.35**	**1.09**	**1.29**	**0.79**	**0.85**	**0.73**	**0.79**
	L	**S**	**L x S**		**L**	**S**	**L x S**	
SE(m)±	0.016	0.011	0.028		0.010	0.006	0.017	
CD at 5%	0.032	0.021	0.056		0.020	0.013	0.034	

Relative Growth Rate

The relative growth rate (RGR) defines the rate of increase in plant mass per unit plant mass already present. Differences in relative growth are referred by differences in leaf area per unit plant mass. Relative growth rate, a measure of biomass accumulation per unit dry weight of the plant is progressively increased up to bud appearance stage and declined subsequently when it attains full flowering irrespective of seasons and variety [Table-2]. The major determinant of RGR is the development and maintenance of photo synthetically active LA. The decrease in RGR was mainly attributed to the shedding of leaves when the plant advanced towards maturity. [8] reported that higher the RGR higher was the yielding ability [8]. Abiotic stress has been reported to reduce the relative growth rate in crop plants [12 and 4].

IAA Oxidase Activity

Results from the present study depicted that the IAA oxidase activity declined during the vegetative and bud appearance stage where activity was more in pre-flowering phase during winter [Table-3]. This might have resulted in the usage of available auxin in inducing cell elongation and shoot growth in early stages. Another reason is that after bud differentiation, there is no need for cell division. So, automatically IAA oxidase activity becomes less in peak flowering process. This is in agreement with findings of [9] in chrysanthemum and [11] in Dendrobium.

Carbohydrate

Sugars may serve as compatible solute permitting osmotic adjustment along with the proline, glycine betaine and mannitol. Sugars may also stabilize proteins under stress. In the present study, the optimum amount of reducing sugars, present in the interrupted lighting (6h & 8h) and continuous lighting (3 h & 4h) with 13 h dark period [Fig-2]. Total carbohydrates were more in bud initiation stage due to the increase in rate of photosynthesis and regulation of source sink relation for better assimilate transport. The presence of more carbohydrate content resulted in more number of flowers. This was well supported by the experimental result and this is line with the findings of [2] in rose.

Table-2 *Effect of photoperiod on relative growth rate (mg g^{-1} day^{-1}) of spray chrysanthemum during winter season*

Treatment	Relative Growth Rate (mg g^{-1} day^{-1})							
	Vegetative stage to Bud appearance stage				Bud appearance stage to Flowering stage			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
L_1	0.0228	0.0204	0.0138	0.0190	0.0046	0.0058	0.0051	0.0052
L_2	0.0143	0.0185	0.0085	0.0137	0.0062	0.0065	0.0091	0.0072
L_3	0.0193	0.0186	0.0122	0.0167	0.0085	0.0062	0.0069	0.0072
L_4	0.0096	0.0090	0.0098	0.0095	0.0050	0.0061	0.0072	0.0061
L_5	0.0076	0.0143	0.0134	0.0118	0.0073	0.0059	0.0059	0.0063
L_6	0.0228	0.0171	0.0125	0.0175	0.0094	0.0073	0.0065	0.0077
L_7	0.0147	0.0147	0.0156	0.0150	0.0083	0.0072	0.0068	0.0074
Mean	0.0159	0.0161	0.0122	0.0147	0.0070	0.0064	0.0068	0.0067
	L	S	L x S		L	S	L x S	
SE(m)±	0.00019	0.00012	0.00033		0.00008	0.00005	0.00014	
CD at 5%	0.00038	0.00025	0.00066		0.00017	0.00011	0.00029	

Table-3 *Effect of photoperiod on IAA oxidase activity (µg of unoxidised auxin g-1 h-1) at critical stages of spray chrysanthemum during winter season*

Treatment	IAA oxidase activity (µg of unoxidised auxin g^{-1} h^{-1}) at critical stages (Punch)											
	Vegetative stage				Bud appearance stage				Flowering stage			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
L_1	136.28	138.64	137.29	**137.40**	73.55	78.09	75.36	**75.67**	56.24	55.34	65.47	**59.02**
L_2	100.24	108.99	105.03	**104.75**	120.35	134.84	130.82	**128.67**	115.32	128.64	117.94	**120.63**
L_3	68.54	73.69	80.29	**74.17**	175.26	168.94	170.33	**171.51**	155.34	143.29	153.02	**150.55**
L_4	93.64	88.29	90.35	**90.76**	138.02	148.67	145.99	**144.23**	117.34	122.34	115.94	**118.54**
L_5	125.47	112.95	120.87	**119.76**	86.86	83.56	89.48	**86.63**	65.24	76.38	70.91	**70.84**
L_6	66.34	75.24	82.65	**74.74**	186.31	172.05	168.34	**175.57**	166.07	145.32	135.69	**149.03**
L_7	95.34	88.64	75.68	**86.55**	126.37	118.24	123.53	**122.71**	100.45	100.23	113.31	**104.66**
Mean	**97.98**	**98.06**	**98.88**	**98.31**	**129.53**	**129.20**	**129.12**	**129.28**	**110.86**	**110.22**	**110.33**	**110.47**
	L	S	L x S		L	S	L x S		L	S	L x S	
SE(m)±	1.256	0.822	2.176		1.639	1.073	2.838		1.411	0.924	2.445	
CD at 5%	2.539	1.662NS	4.398		3.312	2.168NS	5.737		2.853	1.867NS	1.867	

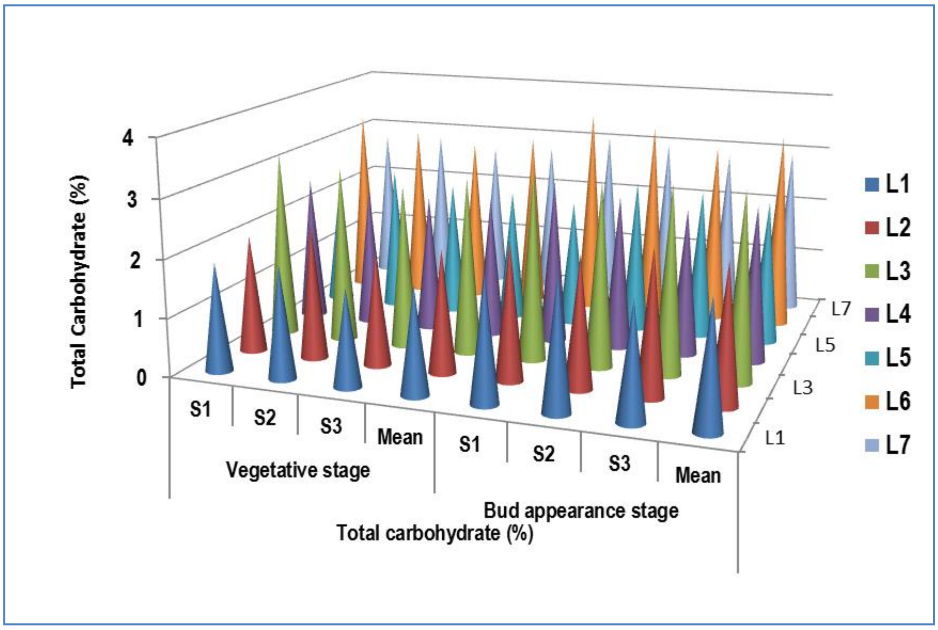

Fig-2 Effect of photoperiod by on total carbohydrates (%) of spray chrysanthemum

Flower Yield

Yield is determined by the number of marketable stems that harvested in a unit area. The effect of light regimes at an interrupted duration improved the growth and flowering parameters. The positive influence of photoperiodic levels at 10 min of continuous light in every 30 min cycle for 8 h (4h supplemental lighting) + 13 h dark (L_6S_1) during winter improved higher percentage of marketable flowers (A, B and C grades) and yield of cut stems/m^2 were obtained for both the types [Table-4]. Per sq. m yield of 78.60 cut stems (L_6S_1) in winter was 25.17 per cent higher than control (L_1S_1) in standard type while 28.16 per cent was higher in spray type. The next best treatment was L_4S_1 with 22.70 per cent increase over control in

Table-4 *Effect of photoperiod on number of quality grade flowers/m² and cut stem yield/m² of spray chrysanthemum during winter season*

Treatment	Number of quality grade flowers/m²												Cut stem yield/m²			
	A Grade				B Grade				C Grade							
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
L_1	0.00	0.00	0.00	**0.00**	24.5	22.2	27.9	**24.91**	36.82	41.24	34.1	**37.41**	61.3	63.4	62.1	**62.32**
L_2	37.7	35.2	55.6	**42.88**	22.9	17.6	3.48	**14.69**	4.92	11.23	4.11	**6.75**	65.5	64.1	63.2	**64.33**
L_3	70.6	57.6	36.8	**55.04**	1.52	11.0	22.8	**11.80**	3.80	5.18	10.5	**6.50**	75.9	73.9	70.1	**73.34**
L_4	57.6	57.5	52.6	**55.93**	8.58	7.01	10.4	**8.54**	2.40	5.61	6.58	**4.86**	68.6	70.1	69.2	**69.33**
L_5	32.3	28.6	30.4	**30.46**	16.1	12.7	14.4	**14.43**	16.16	22.28	19.2	**19.21**	64.8	63.6	64.0	**64.17**
L_6	73.9	69.2	56.9	**66.69**	1.57	2.28	15.2	**6.37**	2.36	4.57	2.23	**3.05**	78.6	76.0	74.3	**76.38**
L_7	51.5	60.0	54.4	**55.38**	12.90	7.07	12.7	**10.89**	9.21	3.53	5.45	**6.06**	73.6	70.6	72.6	**72.33**
Mean	**46.2**	**44.0**	**40.8**	**43.77**	**12.6**	**11.4**	**15.2**	**13.09**	**10.81**	**13.38**	**11.7**	**11.98**	**69.8**	**68.8**	**67.9**	**68.89**
	L	**S**	**L x S**		**L**	**S**	**L x S**		**L**	**S**	**L x S**					
SE(m)±	0.581	0.380	1.008		0.194	0.127	0.337		0.212	0.138	0.368		0.841	0.551	1.456	
CD at 5%	1.17	0.76	2.037		0.39	0.25	0.682		0.42	0.28	0.743		1.69	1.11	2.944	

spray type in winter respectively. The increase in quality of stems might be due to the uniform artificial illumination provided after flower initiation during season of crop growth. [13] and [3] also obtained similar results in chrysanthemum.

Conclusion

It is inferred from the study that during winter, the spray chrysanthemums illuminated with that 10 min of continuous light in every 30 min cycle for 8 h (4 h extended light) along with 13 h short day regime (L_6S_1) had improved the physiological parameters like crop growth rate, net assimilation rate, relative growth rate and IAA oxidase activity at all the critical stages of the crop. The improvement in physiological parameters had influenced the number of quality grade flowers (73.90 stems/m²) and cut stem yield (78.60 stems/m²).

Conflict of Interest: None declared

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