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Effect of elevated carbon-dioxide levels on morphological and physiological parameters in gladiolus

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ABSTRACT

Effect of different CO_2 concentrations, *i.e.*, 400 (control), 700 and 900 ppm on morphological and flowering parameters was studied on two gladiolus cvs. American Beauty and Snow Princess under controlled phytotron conditions. Maximum plant height (76.06 cm) was found at 700 ppm CO_2 concentration in cv. Snow Princess but at 900 ppm, the growth declined. Scape width was found maximum in cv. American Beauty in treatment 900 ppm CO_2. Cultivar Snow Princess was found with maximum spike length (57.32 cm) in 700 ppm of CO_2. Rachis length (21.43 cm), leaf length (48.05 cm), number of spikes/plant (1.67) and flowering duration (6.00 day) were found maximum in cv. Snow Princess with 700 ppm CO_2. Number of days taken for spike emergence and leaf dry weight increased with the rise in CO_2 concentration. Maximum number of days for spike emergence (78.73) were recorded in treatment 900 ppm CO_2 concentration in cv. American Beauty. Number of florets/spike and number of leaves/plant were not affected significantly by the rise of CO_2. Leaf area ratio decreased with CO_2 concentration rise which indicates increase in leafiness of plant. With increase in CO_2 concentration nitrogen content decreased. The lowest nitrogen content in leaves was found at 900 ppm CO_2 treatment. Total chlorophyll (a+b) content was found maximum in 700 ppm of CO_2 but got reduced as the concentration was elevated to 900 ppm.

Key words: Carbon dioxide, flowering, gladiolus, growth, phytotron.

INTRODUCTION

Gladiolus [*Gladiolus* (Tourn) L.] is a monocotyledonous flowering bulbous plant, belongs to Iridaceae family. It is a popular flower plant in national as well as international cut flower trade. It produces magnificent inflorescence with a variety of colours and tall spikes of large blossoms. Gladiolus cultivation in India is done mostly in the open field conditions, which expose the spikes to various kinds of biotic and abiotic stresses and ultimately the quality of flowers is adversely affected. Presently, the atmospheric carbon dioxide (CO_2) concentration is increasing at a rate of about 1 µmol mol^{-1} per year and it is expected to reach 530 µmol mol^{-1} by 2050 and may exceed 700 µmol mol^{-1} in 2100 (Watson *et al.*, 17). Carbon dioxide in the atmosphere is the substrate for photosynthesis and its elevated levels are expected to enhance photosynthesis, which will probably increase growth rate and yield of many crops and also water use efficiency, especially in C_3 plants (Centritto *et al.*, 1; Li *et al.*, 11).

Recent climate change models have projected that global surface air temperature may increase 1.4 - 5.8°C with the doubling of carbon dioxide concentration by the end of the century. These changes in carbon dioxide concentrations and temperature are likely to occur concomitantly, therefore, it is important to evaluate how the temperature dependence of key physiological processes are affected by rising carbon dioxide concentrations in major flower crops including gladiolus. Information about response of CO_2 rise in gladiolus crop is very mearge, hence it was necessary to study its likely impact on morphological and physiological parameters.

MATERIALS AND METHODS

The present study was conducted at the Division of Floriculture and Landscaping and National Phytotron Facility, New Delhi, during 2009-2010. Two commercial gladiolus cultivars, *viz*., American Beauty and Snow Princess were selected for the study. The healthy corms of 3.0 to 4.5 cm dia. from both cultivars were used. Poly vinyl chloride pots (15 cm in dia. and 35 cm depth) were filled with cocopeat (composted coconut husk mixed with perlite) having one inch thick layer of river bed sand at the bottom. The pots were then randomly transferred to growth chambers. The closed plant growth chambers were maintained day and night temperature with 20/18°C. The elevated CO_2 concentrations were maintained at day and night by releasing it from cylinder at 700 and 900 ppm, higher than the ambient. Ambient CO_2 concentration of 400 ppm was taken as control. Throughout the experiment, the plants were irrigated and fertilized at frequencies believed to be sufficient to preclude the development

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of water and nutrient stresses. Plants were fertilized weekly (150 ml of 10% Hoagland's solution) and watered twice a day for the entire experimental period. Required space between light source and plants was maintained to avoid the light injury. Data on various morphological and physiological parameters were recorded and analyzed statistically following complete randomized design (CRD).

RESULTS AND DISCUSSION

The numbers of days taken for corms sprouting was not affected significantly by the different levels of CO_2 concentrations (Table 1). The varietal difference was observed for number of days required to sprouting. Cultivar Snow Princess was found to give earliest corm sprouting (9.63 days) than American Beauty (11.33 days). As the CO_2 concentration increased from the ambient level (400 ppm) to 700 ppm the plant height was enhanced. In treatment 700 ppm, 6.50% more plant height was observed over control (400 ppm), whereas 10.79% increase in plant height over 900 ppm was observed. Plant height was found maximum in 700 ppm of CO_2 concentration in cv. Snow Princess with 8.99 and 14.25% of more plant height was observed over control (400 ppm) and 900 ppm CO_2 concentration, respectively. Similar results were reported by Houpis *et al.* (4) in *Pinus ponderosa* in elevated CO_2 scape width significantly differed with increase in CO_2 concentration. It was found maximum at 900 ppm CO_2 concentration followed by 700 ppm treatment. This can be interpreted by the reduced plant height leading to thicker base or scape diameter. The possible reason for the increased scape width may be reduced plant height, which forms strong plant base. Investigations of Idso *et al*. (6), Martin *et al*. (12) and Syvertsen and Graham (14) on different *Citrus* species indicated an increase of vegetative growth by about 20 to 90% at elevated atmospheric CO_2 concentrations from 660 to 720 ppm.

Carbon dioxide levels did not affect significantly the number of leaves per plant at spike emergence stage (Table 2). Leaf length was found with significant effect of CO_2. Carbon dioxide concentrations of 700 and 900 ppm were found with 9.36 and 6.44% longer leaf compared to control (400 ppm). Number of leaves per plant is a genetic character and that may be the probable reason for non significant effect due to elevated CO_2 levels.

Due to increase in CO_2 concentration, there was significant increase in number of days required for spike emergence. The earliest spike emergence was found in control (400 ppm) but as the CO_2 level was increased there was significant delay in spike emergence. The reason for this response was unclear and need to be further investigated. The number of spikes per plant was also reported with similar results. As the CO_2 concentration was increased, number of spikes per was significantly reduced. The maximum number of spikes per plant was found in control (400 ppm) treatment. Contradictory to this result, Van Labeke and Dambre (16) reported increase in total number of flower stems (m^{-2}) in alstroemeria. Further, Idso *et al*. (5) reported the proportional yield increase due to elevated CO_2 concentration under warmer temperatures but in this experiment the growing temperature was 20/18°C (D/N) this temperature may not be sufficient to utilize the advantage of elevated CO_2. This may be the probable reason for limited effect of enriched CO_2 for higher yield of spikes per plant.

Spike length at flowering stage was significantly affected by different levels of CO_2. Spike length was increased in 700 ppm of CO_2 concentration but significantly reduced as the CO_2 level raised to 900 ppm. The maximum spike length was observed in cv. Snow Princess in 700 ppm of CO_2. Rachis length was enhanced with increase in CO_2 concentration upto 700 ppm. Internodal length was not significantly affected with increased CO_2 concentrations. Van Labeke and Dambre (16) reported improved flower stem quality owing to CO_2 enrichment (higher stem weight and cymes per inflorescence) in two alstroemeria cultivars. Total number of florets per spike and diameter of second floret were not affected significantly by the different levels of CO_2 concentrations. Variation in diameter of second floret was recorded in cultivars which may be due to genotype (Table 2). Cultivar Snow Princess was found with higher diameter of second floret. Maximum number of florets opened at 6^{th} floret withered stage was found in 700 ppm of CO_2.

Total leaf area was significantly affected by different CO_2 levels (Tables 3 & 4). As the CO_2 level increased total leaf area was significantly increased. Similar results were reported by Talawar *et al*. (15) in chickpea. Maximum total leaf area was found at 700 ppm of CO_2 but it was significantly reduced at 900 ppm. Cultivar American Beauty was found with maximum leaf area over Snow Princess. Gutjahr and Lapointe (3) in *Erythronium americanum* reported similar results due to high CO_2 concentration. Li *et al*. (10) in wheat reported 23-45% increase in leaf area with elevated CO_2 and N-added at 55 days after sowing. Similar results were obtained initially up to 700 ppm CO_2 concentration, where leaf area was increased but as the CO_2 level raised to 900 ppm, leaf area was reduced. This may be due to limited availability of nitrogen to leaves. There was significant higher specific leaf weight at 900 ppm CO_2 but there was non significant difference in treatment 700 ppm and control (400 ppm). The reason for the

Table 1. Effect of elevated CO_2 on number of days taken to corms sprouting, plant height (cm), scape width (mm), number of leaves/plant and length of second leaf (cm) in gladiolus.

Treatment	No. of days taken to corm sprouting				Plant height (cm)				Scape width (mm)				No. of leaves per plant				Length of second leaf (cm)			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
American Beauty	11.60	11.07	11.33	11.33	71.99	75.23	69.74	72.32	17.03	18.22	20.18	18.48	7.87	7.47	7.67	7.67	41.50	45.48	44.87	43.95
Snow Princess	10.20	9.07	9.63	9.63	69.47	76.06	65.22	70.25	17.30	18.38	20.76	18.81	6.93	7.33	7.13	7.13	43.30	48.07	45.78	45.72
Mean	10.90	10.07	10.48	-	70.73	75.65	67.48	-	17.17	18.30	20.47	-	7.40	7.40	7.40	-	42.40	46.78	45.32	-
CD at 5%																				
	Treatment (T)			NS				2.73				1.21				NS				1.53
	Genotype (G)			1.11				NS				NS				0.34				0.84
	T × G			1.63				3.31				1.42				0.69				3.43

NS = Non significant, T_1 = 400 ppm (control), T_2 = 700 ppm and T_3 = 900 ppm

Table 2. Effect of elevated CO_2 on number of days taken for spike emergence, number of spikes per plant, spike length, rachis length and internodal length (cm) in gladiolus.

Treatment	No. of days taken for spike emergence				No. of spikes per plant				Spike length (cm)				Rachis length (cm)				Internodal length (cm)			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
American Beauty	68.73	71.20	76.93	72.29	1.47	1.27	1.07	1.27	53.21	54.19	48.35	51.99	17.97	21.43	19.7	19.7	4.45	4.63	4.17	4.42
Snow Princess	57.80	66.2	78.73	67.58	1.67	1.40	1.00	1.36	52.99	57.32	47.14	52.48	20.15	21.89	21.02	21.02	4.37	4.51	4.48	4.45
Mean	63.27	68.70	77.83	-	1.57	1.34	1.04	-	53.10	55.76	47.75	-	19.06	21.66	20.36	-	4.41	4.57	4.32	-
CD at 5%																				
	Treatment (T)			1.38				0.21				1.05				1.03				0.67
	Genotype (G)			2.01				0.11				0.40				0.32				NS
	T × G			2.81				0.34				2.43				1.46				1.07

NS = Non significant, T_1 = 400 ppm (control), T_2 = 700 ppm and T_3 = 900 ppm

Table 3. Effect of elevated CO_2 on spike diameter (mm), diameter of second floret (cm), number of florets per spike, number of florets opened at 6th floret and total leaf area withered stage in gladiolus.

Treatment	Spike diameter (mm)				Diameter of second floret (cm)				No. of florets/spike				No. of florets opened at 6th floret withered stage				Total leaf area (cm^2)			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
American Beauty	8.53	8.76	7.25	8.18	8.34	9.24	8.15	8.58	11.40	10.33	9.67	10.47	4.87	4.90	3.93	4.57	709.77	940.56	728.91	793.08
Snow Princess	9.57	9.33	7.73	8.88	9.06	9.15	8.77	8.99	11.53	12.33	11.00	11.62	5.13	5.60	4.87	5.20	690.56	744.03	761.57	732.05
Mean	9.05	9.05	7.49	-	8.70	9.20	8.46	-	11.47	11.33	10.335	-	5.00	5.25	4.40	-	700.17	842.30	745.24	-
CD at 5%																				
	Treatment (T)			0.93				0.65				0.51				0.31				61.58
	Genotype (G)			0.04				0.03				0.67				0.43				43.70
	T × G			1.12				1.02				1.14				0.71				157.36

T_1 = 400 ppm (control), T_2 = 700 ppm and T_3 = 900 ppm

Table 4. Effect of elevated CO_2 on leaf area ratio and specific leaf weight, total chlorophyll content, dry weight of leaves and total nitrogen in gladiolus.

Treatment	Leaf area ratio				Specific leaf weight				Total chlorophyll (a+b) (mg/g FW)				Leaf dry weight (g)				Total nitrogen (%)			
	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean	T_1	T_2	T_3	Mean
American Beauty	607.27	244.75	229.86	360.62	0.059	0.068	0.062	0.062	0.99	1.28	1.12	1.13	1.55	2.90	3.17	2.54	709.77	940.56	728.91	793.08
Snow Princess	517.03	258.24	239.12	338.13	0.064	0.067	0.061	0.064	0.97	1.22	1.16	1.11	1.44	2.73	3.19	2.46	690.56	744.03	761.57	732.05
Mean	562.15	251.49	234.48	-	0.061	0.067	0.061	-	0.98	1.25	1.14	-	1.50	2.82	3.18	-	700.17	842.30	745.24	-
CD at 5%																				
	Treatment (T)			54.66			0.011					0.07				1.05				0.08
	Genotype (G)			4.31			NS					NS				0.31				0.03
	T × G			95.93			0.01					0.10				0.41				0.31

NS = Non significant, T_1 = 400 ppm (control), T_2 = 700 ppm and T_3 = 900 ppm higher specific leaf weight may due to more leaf thickness which may due to higher CO_2 level (900 ppm). Leaf area ratio was significantly affected by the increase in CO_2 concentration. As CO_2 concentration increased leaf area ratio was decreased. Leaf area ratio indicates the leafiness of plant which was found to increase as CO_2 level was enhanced. Cultivar American Beauty was found with more leafiness over cv. Snow Princess.

Chlorophyll in leaves is the main light harvesting arganelle, which is responsible for the overall growth and development of plants. In present investigation, at 700 ppm CO_2 concentration total chlorophyll (a + b) content was increased over the control (400 ppm). Similarly, Idso *et al*. (7) reported CO_2 enriched sour orange trees contained 75% more total chlorophyll at 700 ppm compared to the ambient level of CO_2 (Table 4). In present investigation, as CO_2 level increased from 700 to 900 ppm, the chlorophyll content in leaves was reduced. Similar results were obtained by Ommen *et al*. (13) in spring wheat flag leaves grown under elevated CO_2 concentrations resulting in a decrease (-4.9%) in chlorophyll content at anthesis. It has been argued (Graham, 2) that elevated concentrations of soluble carbohydrates in leaf suppress the expression of several photosynthetic genes. Among them is LHCII (or cab), which encodes the major light harvesting proteins. Thus, soluble carbohydrate repression, as it occurs in the leaves, should cause a decrease of chlorophyll. This response was detected in strawberry in the higher CO_2 concentration (900 ppm). Gladiolus might have lower chlorophyll content at higher concentration of CO_2, which need to be further studied.

Increase in plant or shoot dry weight by CO_2 enrichment was reported in many horticultural crops. The dry weight of leaves was significantly increased with increase in CO_2 levels (Table 4). At 700 and 900 ppm of CO_2, 46.80 and 52.83% increase in dry weight was observed which was significantly higher over control (400 ppm). In present investigation, the significant increase in the dry weight (11.32%) was observed between the 700 and 900 ppm CO_2 concentrations. Similar results were observed by Zhou and Shangguan (18) in sainfoin (*Onobrychis viciaefolia* Scop.).

In the present study, nitrogen content in the gladiolus leaves was significantly reduced with increase in CO_2 (700 and 900 ppm) levels. In strawberry cv. Elsanta, different macronutrients (N, P, K, Ca, Mg) decreased significantly at elevated CO_2 concentrations (Keutgen *et al*., 7), whereas in *Citrus madurensis* only nitrogen was significantly lower. In strawberry, high CO_2 concentrations resulted in general nutrient deficiency. Keutgen and Chen (9) reported nitrogen decreased in citrus leaves distinctly at atmospheric CO_2 concentrations above 600 ppm in completely expanded and old leaves.

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