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Evaluating gladiolus varieties for off-season planting using agro-meteorological indices

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ABSTRACT

Commercial floriculture is an emerging profitable agro industry in the world with great demand of cut flowers but with a constraint to regulate the supply for longer duration in the markets. The off-season plucked flowers get better price, as glut during peak season affects the profits. This could be achieved by cultivating varieties over a wide range of planting times which demands evaluation of varietal performance under different sowing windows. The present study was conducted with five gladiolus varieties *viz.* Punjab glance, Punjab lemon delight, Novalux, Rose supreme and Alexander the great planted at six sowing dates starting from 5thJuly to 20th September at 15 days interval. All the varieties gave best performance in terms of days to flowering, plant height, spike length, number of florets per spike, vase life and number of corms per corm when planted on 20th September (nearest to normal planting season). The growth of all varieties was affected under early plantings as they produced taller plants with shorter spikes, reduced number of florets per spike and vase life; took more number of days to flower, accumulated more growing degree days (GDD), helio thermal units (HTU) and photothermal units (PTU). All the varieties under early plantings produced spikes of comparable quality that depicts their tolerance to unfavourable temperature and photoperiod. This characteristic could be used in breeding programmes for development of varieties that could efficiently channelize their accumulated heat units for spike production and could be grown in diverse agro climatic zones. The performance of early planted Punjab glance and Punjab lemon delight was at par to their respective normal plantings. Thus, early planting of these varieties will lead to spike production in September and at this time farmers can fetch good price.

Key words: Gladiolus, planting time, GDD, PTU, HTU, flowering

Gladiolus (*Gladiolus grandifloras* L.) is an ornamental bulbous crop, known as 'Queen of bulbous flowers', occupies an important position among cut flowers. It is valued for its beauty, elegance, variant colours and majestic spikes (Chanda *et al.*, 2000; Riaz *et al.*, 2007). Due to wide range of colours and magnificent inflorescence, it is widely used in herbaceous borders, beddings, rockeries, pots and for cut flowers (Abbasi *et al.*, 2005).

Gladiolus crop can grow well in diverse agroclimatic conditions that support its cultivation throughout the globe in open or under greenhouse conditions (Cantor and Tolety 2011). Gladiolus is planted during October-November under North Indian conditions and accordingly flowers are available from December-January. Diverse agro-climatic conditions in Punjab allow commercial cultivation of all varieties of gladiolus. The demand of gladiolus for local as well as distant consumption is increasing day by day and to satisfy the enhanced demand of crop and increase the duration of availability of spikes over longer periods, there is a need for year around production of the crop. Planting dates play a significant role in the flower regulation of gladiolus and by altering the planting dates the vegetative and floral quality can be improved in order to meet the consumer demand (Zubair *et al.*, 2006). The late or early planting of the gladiolus will produce flowers for longer duration that will result in steady supply to the market and will also add up to the landscape. Therefore, by regulating the planting time, flower availability can be increased, particularly duringoff-season innorthern plains that can enable growers to fetch more prices for their produce; glut can be avoided in themarket during main growing season that leads to less remuneration to the growers.

The late or early flowering can fetch more prices in the market only if the quality is maintained. Flowering and flower quality in gladiolus is controlled partially by day length provided temperatures are in proper range. Different planting times are accompanied with different photoperiod, light intensity, temperature, humidity that affects the plant growth and development (Muhammad *et al*., 2013). The proper temperature and light conditions influence the vegetative growth followed by flower development and there after flower quality (Al-Humaid 2004).

Further,the performance of any variety is the product of its genetic makeup and environmental factors as these two factors affect all the traits (Khan *et al*., 2001 and Mushtaq *et al*., 2013). The traits such as yield and quality are influenced by various polygenically inherited traits that are highly vulnerable to environmental changes and the phenotypic characters of a genotype alter under different agroclimatic conditions (Ali *et al*., 2003). High degree of correlation exists between genotype and environment controlling performance of different varieties of gladiolus (Maitra and Satya, 2004 and Rashmi and Kumar, 2014). The changes in temperature and day length concomitant to different planting dates resulted in significant variation in the performance of the crop (Therefore, it is important to evaluate commercially important varieties under different climatic conditions and find out the variety that can perform consistently better. Hence,the present study was planned with objectives to evaluate the performance of gladiolus varieties for early flower production and correlate their performance to temperature and photoperiod prevailing under different planting times.

MATERIALS AND METHODS

The uniform sized corms (3.5-4.0 cm diameter) of gladiolus varieties Punjab Glance, Punjab Lemon Delight, Novalux, Rose Supreme and Alexander the Great were sown and raised in the Research Farms of Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana. The experimental field was thoroughly ploughed and levelled and plots of size 3 x 3 m were prepared. The corms were treated with bavistin (0.2%) before sowing for half an hour to prevent fungal infection. The corms of five varieties of gladiolus *viz.* Punjab Glance, Punjab Lemon Delight, Novalux, Rose Supreme and Alexander the Great were planted on six different times viz. 5th July, 20th July, 5th August, 20th August, 5th September and 20th September. All the recommended agronomical practices for irrigation, weeding, fertilization etc were followed to raise the healthy crop. The following observations were recorded from each planting: number of days to flowering, plant height (cm), spike length (cm), number of florets per spike, vase life (days), number of corms per corm. Following agro-meteorological indices were calculated using daily meteorological data.The growing degree days (GDD) were calculated as given by Cross and Zuber (1972).

Growing degree day (GDD°C day) = $\Sigma[\{(T_{max} - T_{min})/2\} - T_b]$

Helio thermal unit (HTU °C day hour) = Σ (GDD × day length)

Photo thermal unit (PTU°C day hour) = Σ (GDD ×actual bright sun shine hours)

where T_{max} and T_{min} are the daily maximum and minimum temperature (°C), T_b is the base temperature (5°C)

The experimental design was Randomized Block Design and the data was subjected to Analysis of Variance (ANOVA) at CD value of five percent to find out whether any significant difference existed among the planting times for the characters under study (Steel *et al.*, 1997). Correlation analysis was also done to find interdependence of growth response of gladiolus under different planting times with agro meteorological indices.

RESULTS AND DISCUSSION

The commercially significant part of gladiolus is its spike. The profitability of gladiolus production depends upon the time at which the spikes are at harvestable stage so the number of days taken by the crop to come to flower is the prime concern while fluctuating the planting dates for off season production. In the present investigation, five varieties were planted at six different sowing dates each at 15 days interval from 5th July to 20th September. The objective of the experiment was to find the response of gladiolus growth pattern to varying temperature and daylength so we statistically compared the dates of planting for a particular parameter of a variety as the variation among the varieties for different parameters may be attributed to the genetic differences (Rani *et al*., 2007 and Swain *et al* ., 2008).

The days taken to flower varied with varying planting time and were different for different varieties (Table 1). The delay in planting decreased the number of days taken to flower in all varieties. The days taken to flower significantly declined from 83.44 to 78.00 for Punjab glance, 85.33 to 78.77 for Punjab lemon delight, 92.77 to 79.00 for Novalux but no significant decline was observed for Rose suprem and Alexander the great. The July planted gladiolus varieties took more days to flower that can be attributed to dormant corms due to which sprouting was delayed, plant growth was slow down and consequently flowering was delayed. The early flowering in September planting was accompanied with early sprouting, bud initiation followed by flower

Table 1: Effect of different planting time on the number of days taken to flower by different varieties of gladiolus

Date of Planting	Punjab glance	Punjab lemon delight	Novalux	Rose supreme	Alexander the great
5th July (P_1)	83.44	85.33	92.77	91.88	94.55
20th July(P_2)	81.55	81.00	87.11	91.33	94.22
5th Aug(P_3)	80.77	75.22	79.44	92.88	92.90
20th Aug(P_4)	78.11	73.33	79.77	90.77	92.44
5th Sep(P_5)	78.22	74.50	79.00	91.22	92.30
20th Sep (P_6)	78.00	78.77	79.44	89.67	92.44
CD P=0.05)	1.54	2.03	1.85	NS	NS

Table 2: Effect of different planting time on the plant height (cm) of different varieties of gladiolus

Date of Planting	Punjab glance	Punjab lemon delight	Novalux	Rose supreme	Alexander the great
5th July (P_1)	86.33	75.50	66.27	86.83	96.11
20th July(P_2)	88.11	78.90	72.44	88.61	101.50
5th Aug(P_3)	89.12	84.22	78.67	100.94	113.30
20th Aug(P_4)	91.55	93.20	84.40	106.30	122.17
5thSep(P_5)	94.94	97.55	87.05	110.55	130.78
20th Sep (P_6)	102.22	101.38	87.55	110.16	133.27
CD P=0.05)	4.16	4.07	6.10	4.55	4.80

Table 3: Effect of different planting time on the spike length (cm) of different varieties of gladiolus

Date of Planting	Punjab glance	Punjab lemon delight	Novalux	Rose supreme	Alexander the great
5th July (P_1)	59.16	58.44	53.72	59.37	74.05
20th July(P_2)	64.77	62.72	57.30	65.16	78.55
5th Aug(P_3)	68.50	71.61	67.13	73.94	90.27
20th Aug(P_4)	77.11	75.00	71.30	84.80	97.00
5th Sep(P_5)	80.22	80.50	76.88	87.00	99.50
20th Sep (P_6)	81.88	83.38	80.30	88.72	100.27
CD P=0.05)	5.15	4.87	3.64	NS	7.37

initiation so plants attained flowering earlier than July plantings. Similar observations were recorded by Khanna and Gill (1983). The maximum temperature ranged between 32-34°C and minimum between 24-27°C throughout the development of July planted crop whereas September planted crop faced maximum temperature between 31-20°C and minimum between 17-6°C thus comparatively lower temperature and short day conditions under September plantings might have resulted in fewer number of days taken to flower, whereas, higher temperature and long day conditions under July plantings resulted in more number of days for flowering (Laurie *et al*., 1979).

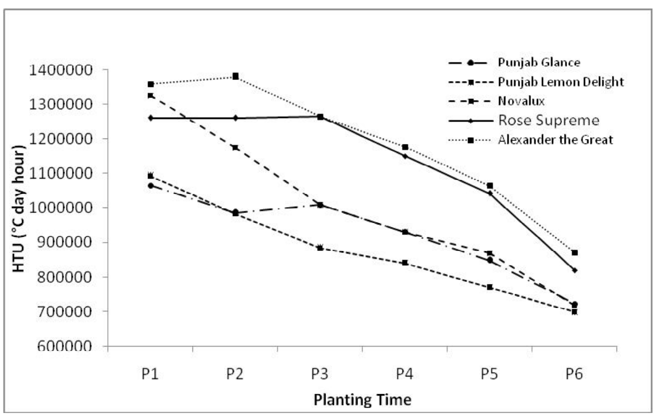
The planting date significantly influenced the plant height of different varieties (Table 2). With delay in planting the plant height increased for all varieties. Except Novalux, plant height of all varieties was at par for P_1 and P_2 planting but then increased significantly with further delay in planting. The maximum increase of 36 cm in plant height from P_1 to P_6 was recorded for Alexander the Great and the corresponding values for Punjab Glance, Punjab Lemon Delight, Novalux and Rose Supreme were 16, 26, 21 and 24 cm. The plant height of September planted gladiolus (all varieties) was maximum which could be attributed to ideal mean temperature and day length during entire plant growth (neither too high nor too low). This temperature and day length provided ideal conditions for photosynthesis due to which plants grew better and attained height (Iwama and Iwai, 1952; Banker and Mukhopadhayay,1980).

Table 4: Effect of different planting time on the number of florets per spike of different varieties of gladiolus

Date of Planting	Punjab Glance	Punjab Lemon Delight	Novalux	Rose Supreme	Alexander the Great
5^{th} July (P_1)	10.72	9.00	7.80	11.22	10.11
20^{th} July(P_2)	10.38	10.27	9.20	12.11	11.80
5^{th} Aug(P_3)	11.11	10.83	9.80	14.11	13.40
20^{th} Aug(P_4)	10.89	11.90	10.27	15.05	14.70
5^{th} Sep(P_5)	12.30	12.20	11.70	15.25	15.20
20^{th} Sep (P_6)	12.50	12.40	11.70	15.16	15.30
CD P=0.05)	1.33		0.58	NS	NS 0.77

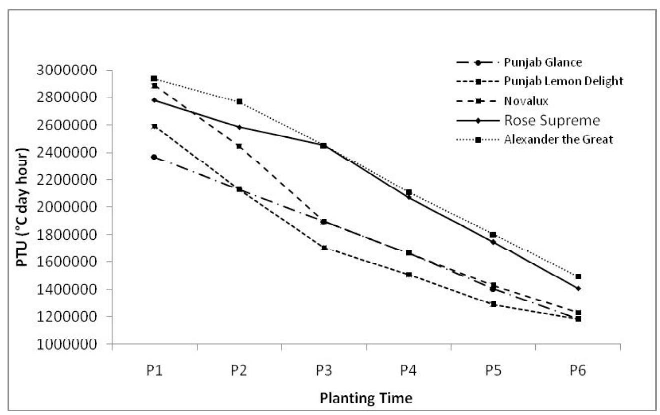
Table 5: Effect of different planting time on the vase life (days) of different varieties of gladiolus

Date of Planting	Punjab Glance	Punjab Lemon Delight	Novalux	Rose Supreme	Alexander the Great
5^{th} July (P_1)	7.05	6.44	6.05	7.44	6.61
20^{th} July(P_2)	7.61	7.22	6.88	9.22	7.89
5^{th} Aug(P_3)	8.72	8.33	8.67	11.70	8.94
20^{th} Aug(P_4)	10.55	10.11	11.30	13.22	11.55
5^{th} Sep(P_5)	12.22	12.05	12.11	14.38	14.11
20^{th} Sep (P_6)	13.30	13.11	12.27	14.22	14.40
CD P=0.05)	0.86	0.45	0.73	0.73	0.53



where P_1-5^{th} July, P_2-20^{th} July,P_3-5^{th} Aug,P_4-20^{th}Aug,P_5-5^{th} Sep, P_6-20^{th}Sep

Fig. 1: Effect of different planting time on heliothermal units (HTU) taken by different varieties of gladiolus from planting to flowering



where P_1-5^{th} July, P_2-20^{th} July,P_3-5^{th} Aug,P_4-20^{th} Aug,P_5-5^{th} Sep, P_6-20th Sep

Fig. 2: Effect of different planting time on photothermal units (PTU) taken by different varieties of gladiolus from planting to flowering

Spike length determines the commercial grade for the marketability of the produce. The planting date significantly influenced the spike length of all varieties (Table 3). Concomitant to plant height, spike length of all varieties except Rose Supreme was at par for P_1 and P_2 planting but then increased significantly with further delay in planting. The spike length of Punjab Glance increased by 22.72 cm with delay in planting from P_1 to P_6 and the corresponding values for Punjab Lemon Delight, Novalux, Rose Supreme and Alexander the Great were 24.94, 26.58, 29.35 and 26.22 cm. The plant height determines the spike length, so taller plants produced longer spikes. The better plant height and spike length of September planting may be attributed to the prevalence of favorable environmental conditions at the time of planting as well as growth and development.The plants developed better root system and underwent luxuriant

Table 6: Effect of different planting time on the number of corms produced per corm of different varieties of gladiolus

Date of Planting	Punjab Glance	Punjab Lemon Delight	Novalux	Rose Supreme	Alexander the Great
5th Jul (P_1)	1.0	1.0	1.0	1.0	1.0
20th Jul(P_2)	1.0	1.0	1.0	1.0	1.0
5th Aug(P_3)	1.0	1.0	1.0	1.0	1.0
20th Aug(P_4)	1.3	1.0	1.0	1.0	1.0
5th Sep(P_5)	1.3	1.1	1.0	1.0	1.1
20th Sep (P_6)	1.4	1.7	1.4	1.0	1.7
CD P=0.05)	0.19	0.24	NS	NS	0.13

Table 7: Effect of different planting time on the growing degree days (GDD) taken by different varieties of gladiolus from planting to flowering

Date of Planting	Punjab Glance	Punjab Lemon Delight	Novalux	Rose Supreme	Alexander the Great
5th Jul (P_1)	2115.1	2159.3	2329.9	2288.3	2348.5
20th Jul(P_2)	2006.4	2002.6	2134.5	2194.6	2264.6
5th Aug(P_3)	1868.5	1783.7	1873.7	2098.8	2096.9
20th Aug(P_4)	1727.7	1653.5	1724.9	1893.2	1909.5
5th Sep(P_5)	1524.2	1476.9	1537.4	1674.2	1695.0
20th Sep (P_6)	1337.4	1336.6	1354.9	1424.6	1452.3
CD P=0.05)	63.63	61.73	67.35	59.88	77.73

growth through efficient photosynthesis under favorable conditions of September planting whereas, in early plantings, plant establishment and growth was poor due to high temperatures and longer daylengths in July and August. Similar results were obtained by Suneetha and Vasanthakumar (1997) who reported the longest spikes under September planting.

The number of florets did not show much variation with delay in planting but the varietal variation in number of florets per spike was observed (Table 4). The number of florets ranged from 10 to 15 in Alexander the Great, 11 to 15 in Rose Supreme, 7 to 12 in Novalux, 9 to 13 in Punjab Lemon Delight and 10 to 13 in Punjab Glance. The ability of the genotypes to produce florets depends upon their genetic makeup. The variation may be due to hereditary traits of these varieties (Baweja and Brahma, 2003; Kumar and Yadav, 2005).

In the present study, it was observed that floret count increased significantly as the planting was delayed from July to September. The least floret number in July planting might be due to reduced growth of plants in terms of their height and spike length (Suneetha and Vasanthakumar, 1997). Further, the floret count is totally dependent on spike length as a significant positive correlation exists between plant height and number of florets per spike (Mishra and Saini, 1990; and Ghimiray, 2005). Concomitant to our findings, Misra (1996) also observed least floret count in July planted gladiolus under Delhi conditions and maximum floret count in September planted crop.

Vase life of different varieties differed significantly under different planting dates (Table 5). The vase life increased with delay in planting and approximately it doubled for all varieties from P_1 to P_6. The significant increase in vase life was recorded from P_2 to P_3 to P_4 to P_5 planting and after that again no significant enhancement was recorded in all varieties. This could be explained as July planted gladiolus came to flower in September and September planted flowered in November and December. The temperature was higher in September (maximum temperature 32°C and minimum 24°C) so vase life was comparatively fewer days than November and December when temperature was low (maximum temperature 26-20°C and minimum 11-5°C). Temperature plays a crucial role in determining the vase life of flowers as it influences the metabolism of flowers regulating their senescence. Low temperature lowers the rate of cell metabolism and thus, delays the respiration rate, ethylene action, pathogen attack and ultimately senescence (Faraji *et al*., 2011).

Table 8: Correlation analysis between growth parameters and agro meteorological indices of different gladiolus varieties under different planting times

	No. of days	Plant height	Spike length	PTU	GDD	HTU	Sunshine hrs	Day length
No. of days	1							
Plant height	0.390*	1						
Spike length	0.183	0.931**	1					
PTU	0.669**	-0.287	-0.508**	1				
GDD	0.557**	-0.374*	-0.584**	0.985**	1			
HTU	0.784**	-0.078**	-0.281	0.948**	0.922**	1		
Sunshine hrs	0.778**	0.668**	0.603**	0.207	0.104	0.478**	1	
Day length	0.812**	-0.114	-0.350	0.972**	0.924**	0.951**	0.366*	1

* Significance at 5% level; **Significance at 1% level

The number of corms produced per corm did not show much difference with delay in planting (Table 6). The significant increase in number of corms with delay in sowing was recorded in Punjab Glance in P_4 planting and in Punjab Lemon Delight and Alexander the Great in P_6 planting. No significant influence of planting date on number of corms was recorded for Novalux and Rose Supreme. The July planted crop produced fewer corms which might be due to reduced plant growth which further yielded minimum number of corms per plant in all the varieties. The increment in corm production during September could be attributed to partitioning of more photosynthates towards underground sinks caused by the low temperatures (Khanna and Gill, 1983; Thakur and Dhatt, 2015).

The heat unit requirement or growing degree days (GDD) required by different varieties to flower decreased significantly with delay in planting (Table 7). The early planting took more GDD to flower as it took more number of days as well as temperature was also high during that time. So, the decrease in heat unit requirements with delay in sowing might be accounted to low temperature prevailing during later stages of September plantings. Further, the reduction in GDD accumulation was also the result of reduction in number of days taken to attain any phenological stages (Bist *et al*., 2019). Among the varieties, Alexander the Great accumulated highest GDD to flower under all dates of planting and Punjab Glance accumulated least to flower. This difference could be accounted to more profuse growth of Alexander the Great than other varieties under study.

The helio-thermal units accumulated by different varieties under different dates of plantings to reach flowering stage decreased with delay in planting from 5th July to 20th Sept (Fig.1). Thecumulative helio-thermal units (HTU) were reduced with delay in planting due to reduction in bright sunshine hours or higher HTU accumulated by early planting could be due to extended phenophase of flowering (Hundal *et al*., 1997).

The accumulation of photothermal units was concomitant to HTU and GDD for all varieties and planting dates. Adecrease in PTU was recorded with delay in planting of gladiolus from 5th July to 20th Sept. The maximum PTU accumulation (°C day hour) for reaching flowering was 2936032 in Alexander the Great under P_1 and least for Punjab Glance (1185694) under P_6.

Punjab Glance being short duration variety accumulated least calendar days, heat units, HTU and PTU for attaining flowering whereas Alexander the Great being a long duration variety accumulated highest calendar days , heat units, HTU and PTU to flower among all varieties under all planting dates.As gladiolus is thermosensitive, the selection of suitable variety for particular planting window is of prime importance.Growing of a suitable variety at an appropriate time is of prime importance for ensuring optimum productivity of any crop (Pathania *et al*., 2019).

Further, the correlation analysis revealed that significant positive correlation was observed between number of days to flower and temperature and daylength as revealed by different indices (Table 8). A significant but negative correlation existed between heat units and plant height (r = -0.374) and spike length (r = -0.584).Day length affected calendar days, heat units, HTU and PTU whereas bright sunshine hours had significant positive influence on calendar days, plant height, spike length and HTU. A strong correlation between plant height and temperature was recorded that resulted in maximum plant height in September planted gladiolus in Peshawar conditions (Muhammad *et* *al*., 2013). The correlation coefficients could be used as an index to select the variables that affect the crop growth and yield (Sidhu *et al*., 2017). The results of correlation analysis supported our findings that early planting in the month of July produced flower in September but at the same time significant reduction in spike length was recorded. The reduced spike length of gladiolus during September is compensated as at this time gladiolus spikes of this size have same or more market price as compared to high quality spikes produced from normal planting in September-October.

CONCLUSION

The normal planting of gladiolus in northern plains is done in October - November and flowering occurs in December - January depending on variety. The temperature ranges between 26-30°C when crop is in vegetative phase during October –November but as temperature lowers down in December- January, along with increase in photoperiod the crop comes to flower. Now, when we planted the crop in July –August, there was higher temperature but the plants accumulated those heat units and grew vegetatively and produced spikes of smaller lengths as the requirement of low temperature and photoperiod for reproductive development was not fulfilled. The normal planted crop accumulated fewer heat units and shorter days with fewer bright sunshine hours but efficiently utilized them for spike production whereas the early planted gladiolus accumulated higher heat units and longer days with more bright sunshine hours but could not efficiently utilize them for spike production. The varieties under study accumulated more heat units but still produce spikes of comparable quality depicts the thermo tolerant characteristic of these varieties that could be used further in breeding programmes for development of varieties that could efficiently channelize their accumulated heat units for spike production. This will enable the farmers to get the short duration varieties that could be planted in months of July and August and will bloom in September with good quality spikes.

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