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Efficacy of Various Planting Times on Yield and Quality of Cut Sunflower (*Helianthus annuus* L.)

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Abstract: Sunflower (Helianthus annus L.) member of family Asteraceae, grown as annual specialty cut flower. A study was conducted to assess the effectiveness of staggered planting times for year-round production of sunflower. Three cultivar 'Vincent's 2 Choice' was used. Sunflower seeds were sown from 1st January to 15th December, 2019, at fortnight intervals for 24 times. Data were collected on production time (d), plant height (cm), stem length (cm), stem diameter (mm), flower diameter (mm), leaf total chlorophyll contents (SPAD), stem fresh weight (g), stem dry weight (g), vase life (d) and flower quality (1-5). Experiment was designed and performed according to randomized complete block design (RCBD) with three replications. Data were analyzed using Fisher's Analysis of variance technique and treatment means were compared by using LSD test at 5% significance level. In sunflower expt., highest plant height (103.7 cm), stem length (101 cm), leaf total chlorophyll contents (53 SPAD), stem diameter (14 mm), stem fresh weight (108 g), stem dry weight (18 g) and flower quality (4.8) were observed in May plantings, when the day temperature was 39oC and sunshine was almost 10.1 hrs. In summary, 15th May is optimal planting time for quality production of sunflower under agro climatic conditions of Faisalabad, Punjab, Pakistan.

Keywords: sunflower, sowing times, quality production

1. Introduction

Cut flowers production is a continuously growing enterprise in global market with abundant opportunities of investment, improvement and entrepreneurship. There exists a huge demand for floriculture related products in this world and such rising demand is giving boost to international flower business (Sudhagar 2013). In Pakistan, availability of favorable agro-ecological conditions and relatively cheaper labor, has enhanced potential of flower production and ultimately, income of growers (Anonymous 2010). Sunflower (*Helianthus annuus*), a member of family Asteraceae, is grown as a twelve-monthly plant which is in all probability the most ancient plant grown for the purpose of oil seed by human beings. This crop is suitable for the areas of warm constituencies of tropics and subtropics. Its higher dependency on light and temperature makes it complex for lesser heat (Mohamed et al. 1992).

Planting times play an important role in plant growth, development and flower quality. Optimal planting time for Gladiolus spp. define its flower quality (Zubair et al. 2006). New species and cultivars were compared at about 50 sites in USA and Canada, which provided a lot of information about production and marketing of these tested species and cultivars (Clark et al. 2010; Green et al. 2010).

Every species of plants has specified temperature requirements to grow optimally and produce flowering. Addition to this, there is an extent of temperature for every specie which is tolerable and allows optimal plant growth, but beyond extreme temperatures above that specific range can show an unwanted prolonged production times or reduce inflorescence quality (Carlson 2010). Both, day length and temperature period are closely related; as day length turns shorter, the temperature cools, accordingly and vice versa. Like in living organisms, and cut flowers, every biological, chemical, and physiological process is affected by temperature (Armitage and Judy 2003).

2. Materials and Methods

This Study was carried at Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, during 2019-2020. In this study experiment was performed to evaluate best planting time for sunflower (*Helianthus annuus* L.) production. Sunflower

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cultivar 'Vincent's 2 Choice' seeds were purchased from a well reputed local importing agency. Nursery was raised-out in 72 cells plastic trays having soil media silt, coco coir and sugarcane pressmud (1:1:1; v/v/v) as substrate. Seeds were sown at fortnight intervals from 1st January, 2019 to 15th December, 2019. Seedlings were transplanted at 2 to 4 true leaves stage, after thorough preparation of soil and addition of fertilizer (DAP @ 250 kg hac^{-1}). Plant to plant and row to row distance was 15 cm. Rest of the cultural practices like irrigation, fertilization, IPM, IWM, etc. were homogenous for all treatments throughout the study. Seedlings were transplanted on flat beds. Each replication consisted of fifty plants and three replications of all treatments were made, through randomized complete block design (RCBD).

2.1 Treatments and Measurements

Treatments included subsequent sowings on 01 January, 15 January, 01 February, 15 February, 01 March, 15 March, 01 April, 15 April, 01 May, 15 May, 01 June, 15 June, 01 July, 15 July, 01 August, 15 August, 01 September, 15 September, 01 October, 15 October, 01 November, 15 November, 01 December and 15 December. For data collection, five plants from each replication were randomly selected, tagged and data were collected for following morphological parameters, Production time (days) was recorded from date of transplanting to the flower opening, which is the time to harvest first marketable stem. Days were counted and average was calculated. The height of the plant was measured at harvest with meter rod from base to the top of the plant in centimeters. The Measurement of stem length was taken after harvest starting from bottom to the top of flower in cm with the meter rod and mean was noted. Five healthy and newly mature leaves were harvested and total chlorophyll contents were measured from tip, middle and bottom of leaves with digital leaf chlorophyll meter (PN: 0131) and average was recorded. Diameter of open flower was measured with digital vernier caliper (LF 07) from 5 different stems from each replication and average was computed. Stem diameter was measured from center of the stem with digital vernier (LF 07) caliper from 5 stems and average was computed. Five stems from each replication were weighed on electric weighing balance model (HK-DC-320AS) after harvest average was calculated. Stems were packed in average size brown colored paper bag and placed under shady area until moisture dryness occurred. Paper bags were marked accordingly and dried in laboratory oven model (DHG-9053A) at temperature of 65º C for 48 hours constantly. After this, stems were reweighed to note the dry weight and reach an average quantity. The qualitative measurement of flower, was achieved after consideration of flower size, buds and color development. Three different judges rated the flower at a scale of 1-5 (1 means poor, 3 means average while 5 meant for best) according to the (Dest and K. Guillard 1987) method and average was noted. Stems were recut to a length of 50 cm and placed in distilled water until termination in postharvest evaluation room at a temperature of 22 ± 2º C alongwith the light period of 12 hours. Vase life was considered to be ended when stems showed wilting, drooping and senescence of flowers on ≥ 50% of stem.

2.2 Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) technique according to Fisher's technique of analysis (statistix 8.1) and treatment means were compared according to Least Significance Difference test at 5% level of probability (Steel et al. 1997).

Table 1. Meteorological data of research area during study period

Month	**Temperature**			**Relative* Humidity (%)**	**Rainfall* (mm)**	**Sunshine* (hrs.)**
	Max. (ºC)	Min. (ºC)	Avg. (ºC)			
January, 2019	19.2	07.0	13.1	80.7	18.0	05.4
February, 2019	20.3	09.1	14.7	79.0	14.7	06.7
March, 2019	26.0	13.8	19.9	68.5	55.7	08.9
April, 2019	35.0	20.6	27.8	42.5	31.2	09.0
May, 2019	39.0	23.9	31.4	46.5	39.1	10.1
June, 2019	42.4	27.4	34.9	47.8	35.5	10.1
July, 2019	38.0	28.0	33.0	62.7	102.8	07.4
August, 2019	38.0	28.5	33.2	72.5	80.9	07.7
September, 2019	37.7	27.8	32.8	70.1	21.8	08.3

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3. Results

3.1 Production Time (days)

Data regarding production time of sunflower were analyzed using analysis of variance technique and results are presented in Table 2 as comparison of means. Results depicted highly significant differences ($P< 0.001$) among production time of sunflower, when grown in February or in April. Plants grown in February or April, 2019 took least days (30.5 d) to produce flowers followed by (34 d) plants grown in January or March and (35.6 d) in June and July. Whereas, plants grown in November took longest time to produce flowers (60.5 d).

3.2 Plant Height (cm)

Plant's height data of sunflower, were analyzed using analysis of variance technique and results are enlisted in Table 2 as comparison of means. Results demonstrated highly significant differences (P< 0.001) in plant height of sunflower. Tallest plants (103.7 cm) were observed when grown in May followed by (101.1 cm) grown in April. Whereas, shortest plant height (47.5 cm) were observed in the plants grown in January.

3.3 Stem Length (cm)

Data regarding stem length of sunflower were analyzed using analysis of variance technique and results are presented in Table 2 as comparison of means. Results depicted highly significant differences (P< 0.001) among stem length of sunflower. Maximum stem length (101.7 cm) was observed in the plants grown on 15th May. Whereas, minimum stem length (27.2 cm) was observed in the plants grown on 15th November, 2019.

3.4 Stem Diameter (mm)

Data regarding stem diameter of sunflower were analyzed using analysis of variance technique and results are presented in Table 2 as comparison of means. Results disclosed highly significant differences (P< 0.001) among the stem diameter of sunflower when grown in different dates. Maximum stem diameter (14.23 mm) were observed in the plants grown on 1st July, 2019. Whereas, minimum stem diameter (4.5 mm) were observed in the plants grown on December 15, 2019.

3.5 Leaf Total Chlorophyll Content (SPAD)

Data of leaf total chlorophyll content of sunflower were analyzed using analysis of variance technique and results are presented in Table 3 as comparison of means. Results represented highly significant differences (P< 0.001) among leaf total chlorophyll content of sunflower when grown on different dates. Maximum leaf total chlorophyll contents (53.0 SPAD) were observed when grown on 15th May. Whereas, minimum leaf total chlorophyll contents (39.6 SPAD) were observed when grown on 1st October.

3.6 Flower Diameter (mm)

Data regarding flower diameter of sunflower were analyzed using analysis of variance technique and results are presented in Table 3 as comparison of means. Results illustrated highly significant differences (P= 0.001) among flower diameter of sunflower when grown on different planting times. Maximum flower diameter (145.3 mm) were observed when grown on 1st September. Whereas, minimum flower diameter (65.7 mm) were recorded when grown on 15th November.

Table 2. Effect of different planting times on production time, plant height, stem length and stem diameter of sunflower (*Helianthus annuus* L.). All data represents means of 15 plants.

Treatments	Production Time (days)	Plant Height (cm)	Stem Length (cm)	Stem Diameter (mm)
Jan, 01	30.6 l^{z}	45.6 e^{z}	43.2 e^{z}	11.2 cd^{z}
Jan, 15	34.8 k	47.5 i	45.1 i	7.1 k
Feb, 01	30.5 l	60.8 h	58.2 h	9.1 fgh
Feb, 15	36.9 i	68.7 fg	66.6 fg	8.5 ghij
March, 01	36.8 i	68.5 fg	66.6 fg	8.9 fghi
March, 15	34.7 k	69.5 f	67.2 f	9.5 efg
April, 01	35.4 j	101.1 a	99.1 a	10 ef
April, 15	30.5 l	100.2 a	98.1 a	9.8 ef
May, 01	37.3 h	86.7 c	84.6 c	9.7 efg
May, 15	43.1 c	103.7 a	101.7 a	12.5 b
June, 01	35.7 j	99.2 a	97.3 a	12.3 bc
June, 15	38.3 g	79.7 de	77.7 de	14 a
July, 01	39.5 f	81.7 d	79.5 d	14.2 a
July, 15	35.6 j	77.2 de	75.2 de	11.3 cd
Aug, 01	38.5 g	92.6 b	90.5 b	11.6 bcd
Aug, 15	40.7 e	47.4 i	45.4 i	10.4 de
Sep, 01	41.5 d	78.6 de	76.7 de	12.3 bc
Sep, 15	38.5 g	64.5 gh	62.5 gh	8.1 hijk
Oct, 01	43.5 c	48.3 i	46.3 i	7.6 jk
Oct, 15	37.5 h	39.1 j	37.1 j	7.8 ijk
Nov, 01	60.5 a	38.1 jk	36.1 j	7.5 jk
Nov, 15	45.7 b	28.7 l	27.1 k	4.7 l
Dec, 01	38.2 g	39.4 j	37 j	7.7 ijk
Dec, 15	39.5 f	34.5 k	32.5 j	4.6 l
Significance^{y}	< 0.0001	< 0.0001	< 0.0001	< 0.0001

^{z}Mean sharing different letters in the column are statistically different at $P \leq 0.05$.

^{y}P values were obtained using general linear models (GLM) procedures of statistics (version 8.1 analytical software) for effect of different planting times on quality production of sunflower.

3.7 Stem fresh Weight (g)

Data related to stem's fresh weight of sunflower, were analyzed using analysis of variance technique and results are columned in Table 3 as comparison of means. Results outlined highly significant differences (P< 0.001) among stem fresh weight of sunflower when grown on different sowing dates. Maximum weight of fresh stem (108.1 g) were observed in the plants grown in June, 2019. Whereas, minimum fresh weight of a stem (17.4 g) were observed in the plants grown on 15th December, 2019. However, among all year round planting dates, it was observed that plants that were planted in June, July produced maximum fresh weight than others.

3.8 Stem dry Weight (g)

Data concerned to stem dry weight of sunflower were analyzed using analysis of variance technique and results are tabulated in Table 4.4.3 as comparison of means. Results showed highly significant differences (P< 0.001) among stem dry weight of sunflower when grown in all year round. Maximum dry weight of a stem (18.4 g) were observed in the plants grown on 1st July, 2019 followed by (18.0 g) on 15th June, 2019. Whereas, minimum dry weight of a stem (2.4 g) were observed in the plants grown on 15th November, 2019.

3.9 Flower quality (1-5)

Data regarding production time of sunflower were analyzed using analysis of variance technique and results are listed in Table 4 as comparison of means. Results depicted highly significant differences (P< 0.001) among flower quality of sunflower when grown in different sowing dates all round year. Significant results regarding flower quality (4.8) were observed in the plants grown on 15th May, 2019 followed by (4.5) sown on 15th June, 2019. Whereas, least significant results (1.2) were observed in the plants grown on 15th November, 2019.

3.10 Vase life (days)

Data regarding vase life of sunflower were analyzed using analysis of variance technique and results are entered in Table 4 as comparison of means. Results depicted highly significant differences (P= 0.001) among vase life of sunflower when grown on different sowing dates throughout year. Maximum vase life (18.2 d) was observed in the plants grown on 1st August, 2019. Whereas, minimum vase life (3.8 d) was observed in the plants grown on 1st May, 2019.

Table 3. Effect of different planting times on leaf total chlorophyll contents, flower diameter and stem fresh weight of sunflower (*Helianthus annuus* L.). All data represents means of 15 plants.

Treatments	Leaf total chlorophyll Contents (SPAD)	Flower diameter (mm)	Stem fresh weight (g)
Jan, 01	42.3 ghi[z]	99.9 defg[z]	82.3 bc[z]
Jan, 15	50.8 bc	78.8 h	25.9 ij
Feb, 01	52.7 ab	93.5 fg	40.2 efghi
Feb, 15	46.8 ef	91.3 g	31.5 ghij
March, 01	47.4 def	93.6 fg	47 efg
March, 15	49.7 cd	101.1 defg	41.3 efghi
April, 01	42.5 gh	102.3 def	47.2 efg
April, 15	42.3 ghi	100.7 defg	47 efg
May, 01	44.9 g	109 d	69.9 cd
May, 15	53.0 a	124.3 bc	107.6 a
June, 01	42.1 hij	120.8 c	107.1 a
June, 15	43.0 gh	121.6 bc	108.1 a
July, 01	43.4 gh	123.5 bc	103.7 a
July, 15	48.1 cde	104.6de	79.7 c
Aug, 01	48.1 cde	132 b	96.7 ab
Aug, 15	42.5 gh	100.2 defg	45.2 efgh
Sep, 01	42.5 gh	145.3 a	103.7 a
Sep, 15	39.6 ij	95.1 efg	48.6 ef
Oct, 01	39.3 j	95.2 efg	30 hij
Oct, 15	42.2 ghi	72.8 hi	26.4 ij
Nov, 01	43.6 gh	68.2 i	33.1 fghij
Nov, 15	49.2 cde	65.7 i	17.5 j
Dec, 01	45.1 ef	100.6 defg	56 de
Dec, 15	43.7 gh	75.5 hi	17.4 j
Significance	< 0.0001	< 0.0001	< 0.0001

[z]Mean sharing different letters in the column are statistically different at $P \leq 0.05$.

[y]*P* values were obtained using general linear models (GLM) procedures of statistics (version 8.1 analytical software) for effect of different planting times on quality production of sunflower.

Table 4. Effect of different planting times on stem dry weight, flower quality and vase life of sunflower (*Helianthus annuus* L.). All data represents means of 15 plants.

Treatments	Stem dry Weight (g)	Flower Quality[z] (1-5)	Vase Life (days)
Jan, 01	10.5 bc[y]	3.9 bc[y]	4.9 ij[y]
Jan, 15	4.2 hij	4.2 abc	4.5 j
Feb, 01	5.5 gh	4.2 abc	4.7 j
Feb, 15	5.2 ghi	4.1 abc	7.3 g
March, 01	7.7 ef	3.7 bc	7.0 g
March, 15	6.6 efg	4.3 ab	4.5 j
April, 01	8.1 de	4.1 abc	5.5 h
April, 15	5.5 gh	4.2 abc	4.5 j
May, 01	11.2 bc	4.1 abc	3.8 k
May, 15	18 a	4.8 a	5.3 hi
June, 01	18.3 a	4.3 ab	5.4 h
June, 15	11.8 b	4.5 ab	9.5 e
July, 01	11.1 bc	4.2 abc	9.5 e
July, 15	9.4 cd	3.7 bc	4.8 j
Aug, 01	10.8 bc	2.8 de	4.8 j
Aug, 15	5.4 ghi	2.7 de	18.2 a
Sep, 01	11.1 bc	4.5 ab	15.5 b
Sep, 15	5 ghi	2.3 fe	8.1 f
Oct, 01	3.7 ijk	3.4 cd	9.2 e
Oct, 15	5.6 gh	1.8 fg	14.1 c
Nov, 01	4.5 hi	1.3 g	11.9 d
Nov, 15	2.4 k	1.2 g	9.7 e
Dec, 01	6.3 fg	3.9 abc	9.3 e
Dec, 15	2.7 jk	2.5 def	8.1 f
Significance[x]	< 0.0001	< 0.0001	< 0.0001

[z]Flower quality 1= Poor, 2= Fair, 3= Good, 4= Very good, 5= Excellent

[y]Mean sharing different letters in the column are statistically different at $P \leq 0.05$.

[x]*P* values were obtained using general linear models (GLM) procedures of statistics (version 8.1 analytical software) for effect of different planting times on quality production of sunflower.

6. Discussions

Earliest production of sunflower was observed in February to April sowing, which shows that as the temperature increases production time of sunflower decreases. Sunflower grown at 35°C produced early flowers, while those grown at 25°C took longer time to produce flowers. The different plant species and their each cultivar show different responses in accordance to their potential in various agro-ecological conditions (Blaine 1999). Results disclosed that planting times had much influence on production time of sunflower, which were grown round the year. However, sowing during warmer temperatures proved more suitable than cooler season. There is a collective but positive affect of photoperiod, temperature, and humidity on quality flower production (Hong et al. 1989). Different dates of harvesting of different cultivars of amaranth, lisian thus and celosia were also affected by sowing times (Wien 2008). Similarly, (Dole 2001) investigated staggered production time of many cut flowers, this was might be response of type of cultivars e.g. early, mid-season and late cultivars available in market, which were developed according to their days of maturity and potential to tolerate ecological conditions.

Highest plant height was observed in plants that were planted at 39°C in May, while shortest plants were observed in December when the temperature was 16°C. This experiment shows that there is highly positive correlation between temperature and plant height. These results are closely related to the findings of (Swain et al. 2008) who reported that the maximum plant height, growth and flowering was superior in Oct.10 planting in comparison to other plantings. Highest stem length was observed in plants that were planted at 39°C in May, while shortest stem length was observed in December when the temperature was 16°C. This experiment shows that there is highly positive correlation between temperature and stem length.

These results are related to the findings of (Starman et al. 1995) who reported that the number of harvestable stems and stem length of 20 annual species and 20 perennial as well, specialty cut flowers, also different cultivated varieties of *Antirrhinum majus* L., *Matthiola incana* L., *Zinnia elegan* L. and *Liatris spicata* L. were extremely profitable because of high number of harvested stems with suitable stem length. Similar to previous, (Green et al. 2010), also presented harvest season, flowering stem length, head size and diameter local and 'Strawberry Fields' globe amaranth and 'Chief Mix' and 'Pink Candle' cockscomb celosia, which showed considerable variations among cultivars.

Results described that sunflower grown at 42.4ºC produced thickest stem diameter as compared to those that were planted at 16ºC. This shows positive correlation between temperature and stem diameter. Plants with widest stems keep more potential to resist breakage and bending in response to environmental stress. Plants grown in winter produced very thicker stem than the plants that were grown in summer. The results are closely related to the study of (C. Pasian and J. Lieth 1994) who had reported that low temperature induces reduction in diameter and length of spike. Highest amount of chlorophyll contents was observed in May when the temperature was 39ºC and sunlight was almost 10 hrs. And lowest amount of chlorophyll contents was observed when the temperature was 32oC and sunlight was almost 8hrs. These results are analogous to the research findings of (Geeta et al. 2014) who reported maximum amount of chlorophyll contents may be due to the maximum amount of sunlight absorbed by the plant. Due to more photosynthetic activity maximum amount of photosynthates accumulated in plant which results in larger amount of leaf total chlorophyll contents.

Out season planting times resulted in smaller flower diameter while normal planting times produced larger flower diameter. However, among all the tested treatments (sowing dates) of sunflower, results showed that flower diameter was increased when planted in summer or full sunny days. This is might be due to planting time regulates growth and production of quality stems of gladiolus (Khan et al. 2008).

Highest fresh weight of stem (108.1 g) was recorded at 42.4ºC during planting in June and lowest fresh weight (17.4 g) was recorded in the plants that were planted in December at 16.7 ºC. A useful correlation among temperature and fresh weight of stem was noted. These results are familiar to the work of (Ko et al. 2015), who stated that increased fresh weight of chrysanthemum flower at 17ºC as compared to 21ºC in a winter greenhouse experiment.

Results showed useful interconnection between temperature and weight of dried weight of stem. Highest stem dry weight (18.4 g) was observed at 38ºC in the course of these planting weeks, on the other hand, lowest dry weight (2.4 g) was recorded at 25 ºC during November transplantation at low temperatures. These results are in accordance with the findings of (Bose and Tripathi 1996) who wrote that increased dry matter production at high temperature may be attributed to greater accumulation of photosynthates by vegetative parts in gladiolus.

Organic matter and P content in soil affects the quality of flowers. Presence of organic matter in the soil and an ideal amount of macro-nutrients manipulate plant growth and flowering. Good quality flowers may be due to the presence of maximum amount of essential nutrients. Overall flower quality of sunflower was degraded when planted in out of season. Plants grow faster under high temperature and have poor flower quality while petal pigmentation is high in low temperatures (Kinet 1985). Excellent flower quality depends over the type of cultivar being grown in specified area, if the cultivar is befits in that agro-climate, it will produce excellent flower quality and will capture consumer's demand (Devecchi and E. Barni 1997).

Earlier planting times are more positive in results related to growth and development of sword Lily and ultimately enhanced vase life (Imanishi et al. 2002). Cut flowers with excellent post- harvest longevity always fetch good market prices. Lengthy post-harvest life, ability to be sold fresh or even dried, pest and diseases resistance, more than 45 cm long height of stems, easy processes of harvest and handling, aesthetically attractive elegant flowers, foliar and stem beauty are most considerable characteristics, low input cost and high yielded production per unit land and return of high revenue with high demands in market (Starman et al. 1995; Stevens 1998). (Armitage and Laushman 2003) and (Dole et al. 2009) reached a conclusion i.e. stem length of cut species of flowers varies with respect to species and cultivars. Most of the time, influenced by post-harvest handling, quality of vase preservative solutions, instead of planting time and other cultural practices.

7.Conclusions

Production of sunflower is temperature depended, significantly change by weather. Climate change is severely effected on yield productivity. Change in sowing time maybe suitable for sunflower production. . Plants grown in winter produced very thicker stem than the plants that were grown in summer. The maximum plant height, growth and flowering was superior in Oct.10 planting in comparison to other plantings. Sunflower grown at 42.4ºC produced thickest stem diameter as compared to those that were planted at 16ºC. This shows positive correlation between temperature and stem diameter. Increased fresh weight of chrysanthemum flower at 17ºC as compared to 21ºC in a winter greenhouse experiment. Presence of organic matter in the soil and an ideal amount of macro-nutrients manipulate plant growth and flowering. Good quality flowers may be due to the presence of maximum amount of essential nutrients. Overall flower quality of sunflower was degraded when planted in out of season. . Stem length of cut species of flowers varies with respect to species and cultivars. Most of the time, influenced by post-harvest handling, quality of vase preservative solutions, instead of planting time and other cultural practices.

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