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The influence of calcium sources and its application methods on the post-harvest phenological and physical quality attributes of gladiolus spikes

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The influence of calcium sources on the post-harvest performance of gladiolus cut flowers was evaluated by applying 200 mM calcium from various sources (calcium chloride, calcium sulfate, calcium nitrate and calcium gluconate) through two different application methods i.e., vase holding solution and foliar application method, during the years 2016-2017. The post-harvest phenological and physical aspects of gladiolus cut flowers/ spikes were significantly affected by calcium sources and method of calcium application. The addition of calcium chloride in vase solution resulted in the maximum days to 1st floret opening (2.87 days), 1st floret fading (7.71 days) and full spike fading (14.98 days), fresh and senesced floret weight (9.36 and 7.16 g respectively) as well as the least weight loss (7.41%) in florets. It was concluded from the findings of research that calcium chloride was the best source among various sources of calcium when applied in holding solution as compared to foliar application method for retaining post-harvest quality of gladiolus florets/spikes with improved phenological and physical attributes

Keywords: calcium, gladiolus, post-harvest attributes, cut flowers

INTRODUCTION

Floriculture is an important sector of horticulture, with Netherlands, the leading country for the cut flowers trade in the world (Van Uffelen and De Groot, 2005; Van Hemert, 2005). The floriculture is a fast growing and dynamic industry, with trade worth of 60 billion dollars ($) during the year 2003. The Netherlands has the maximum share in export in cut flower industry (Van Uffelen and De Groot, 2005). The Gladiolus grandiflorus is a member of family Iridiaceae and is famous for its cut flowers worldwide (Bhujbal et al., 2013). The gladiolus is cultivated on an area of 7,384.34 ha in the world with an international trade worth 3,100 million US $ (Liemt, 1999; Lepcha et al., 2007). In Pakistan, the gladiolus ranks second among the commercially grown flowering plants after rose (Riaz et al., 2007). It is reported that area under gladiolus cultivation in Pakistan has been increased from 392.54 ha in 2005 to about 809.37 ha in 2015 (Ramzan et al., 2010; Anonymous 2015). The gladiolus is commonly used in flower beds in landscape, in exhibitions and flower shows and most importantly as cut flowers in various forms (Lepcha et al., 2007). Being a major commercial flower, the increased production of gladiolus with quality spikes can increase farmers' income especially in the rural and semi urban areas (saeed et al., 2013). Factors that affect the quality and market value of gladiolus are determined by spike length, floret size, spike compactness and freshness of intact flowers (Da Silva, 2003). Being highly perishable, rapid decay of the gladiolus spikes during postharvest handling is a serious problem that limits increased adaptation of gladiolus as a

commercial crop (Saeed et al., 2013a). The gladiolus needs optimum post harvest management practices to maintain its market value (Malakouti, 2003). The rapid loss of quality and market value of cut flowers of gladiolus necessitates that measures are to be taken to reduce post-harvest losses (Salunkhe et al., 2012). However, the loss in quality of cut flowers is one of the main problems of commercial growers (Faraji et al., 2011). The rate of post harvest quality losses in gladiolus could be minimized by developing proper post harvest protocol/ technology for cut flowers of gladiolus (Saeed et al., 2013b).

The calcium is a multifunctional nutrient and its deficiency causes breakdown of stem in vase water, membrane leakage in petals with water soaked appearance (Wolz, 2001; Easterwood, 2002). Being part of cell wall, calcium improves the strength of the cell wall, thereby, delays senescence (Ferguson, 1984; Easterwood, 2002). The beneficial effects of calcium in retaining cell membrane integrity, that is, generally lost, during senescence in petals are reported by several researchers (Halevy, 1976; Borochov and Woodson, 1989; Itzhaki et al., 1990; Rubinstein, 2000). An optimum intra-cellular concentration of calcium inhibits and delays the senescence (Ferguson, 1984; Leshem, 1992). The calcium is known to reduce the reactive oxygen species (Agarwal et al., 2005) by increasing antioxidant activity. The calcium, therefore, improves the phenological and physical attributes of cut flowers (Sairam et al., 2011; Singh et al., 2013). It strengthens the cell membrane (Marschner, 1995) and enhances longevity of cut flowers (Van Ieperen and Van Gelder, 2006). Contamination of vase water due to bacteria causes reduction in vase life of cut flowers (Van Doorn et al., 1989) while post harvest treatment with calcium and anti-microbial compounds such as chlorine are found effective measures to develop resistance against pathogen (Tobias et al., 1993; Beura et al., 2001).

Post harvest application of calcium in vase solution influence opening of flowers and slow down the senescence process in roses (Torre et al., 1999) by increasing water flow as it is associated with pectin in the xylem cell wall (Van Ieperen and Van Gelder, 2006). However, the calcium is being utilized from various sources available in market such as calcium chloride, calcium carbonate, calcium nitrate, calcium gluconate and calcium sulfate etc that may vary considerably in efficiency (Hodges, 2010). Whereas calcium sulfate causes a reduction in solubilization of pectin and reduces weight loss in highly perishable fruits of blue berries (Angeletti et al., 2010), calcium chloride was found more effective in loquat (Eriobotrya japonica) (Akhtar et al., 2010) and peaches (Manganaris et al., 2007). Treatment of calcium sulfate reduces gray mold infection and increases vase life of cut flowers in roses (Capdeville et al., 2005). Simiallry, Calcium chloride was found to enhance the flower quality and vase life in tuberose (Mortazavi et al., 2016). Foliar spray of calcium nitrate increases longevity of gladiolus cut flowers (Reddy and Sarkar, 2016). Keeping in view the importance of calcium and its various sources for retaining the quality gladiolus spikes, an experiment was planned with the objectives to investigate the best source of calcium and its application method for enhanced phenological and physical post-harvest attributes of gladiolus spikes.

MATERIALS AND METHODS

An experiment was conducted to study the influence of calcium sources and application methods on the phenological and physical post-harvest attributes of gladiolus spikes. For this purpose, gladiolus cv. White prosperity was used as test plant. The experiment was carried out at Post-harvest Lab., Department of Horticulture, The University of Agriculture, Peshawar during 2016-2017. The experiment was laid out as completely randomized design (CRD), having two factors i.e., calcium sources (Distilled water, tape water, calcium chloride, calcium sulfate, calcium nitrate and calcium gluconate) and application methods (Holding solution and Foliar application method). Fresh cut spikes of gladiolus cv. 'White prosperity' were harvested early in the morning from the field. The cut spikes at the stage with basal two to three buds showing color were sorted out and spikes were re-cut under water with uniform size (90 cm). The spikes were placed in glass jars in Lab. at 25ºC (±2) with relative humidity 70 % (±5). The spikes in jars were subjected to various sources of calcium solutions with two application methods i.e., holding solution and foliar application method. Distilled and tape water were used as double control. All solutions were prepared in distilled water. Treatments were repeated three times. The concentration of calcium was kept 200 mM. Data were recorded on various phenological and physical attributes such as days to 1st floret opening, days to full spike opening, days to 1st Flore fading, days to full

spike fading, fresh floret weight, senesced floret weight and weight loss (%).

RESULTSAND DISCUSSION

Calcium Sources and Application Methods in Relation to Phenological Development

Days to 1st floret opening

Statistical analysis of the data (Table 1) showed that significant variations were observed in days to 1st floret opening in response to calcium application methods, sources of calcium and their interaction. The data pertaining days to 1st floret opening in response to post harvest treatment of spikes with different application methods and sources of calcium are shown in Table 2. The two years mean data relating to various sources of calcium showed that calcium chloride resulted in maximum days (2.683) to 1st floret opening, followed by 2.150 days in spikes of gladiolus treated with calcium gluconate. The least days to 1st floret opening (1.681) were recorded in spikes of gladiolus treated with distilled water. The average data across two years regarding application methods indicated that 1st floret opening took more days (2.076) in spikes of gladiolus placed in holding solution of calcium, as compared to (1.977 days) in florets of spikes treated with foliar applied calcium. The mean data regarding interaction across two years between calcium sources and calcium application methods (Figure 1) showed that 1st floret opening was delayed to the maximum (2.87 days), when gladiolus spikes were treated with calcium chloride in holding solution followed by 2.20 days with calcium gluconate. In case of foliar applied method, maximum days (2.50) to 1st floret opening were recorded in spikes treated with foliar applied calcium chloride whereas earliest 1st floret opening (1.68 days) was found in spikes treated with distilled water through both methods. Though maximum delay in 1st floret opening was recorded in spikes treated with calcium chloride with both application methods, however delay in 1st floret opening was (12.9%) more in spikes placed in holding solution of calcium chloride as compared to its foliar application (Figure 1).

Days to full spike opening

The statistical analysis of the data showed that calcium sources and calcium application methods affected the days to full spike opening significantly, while the interaction between calcium sources and application methods had no significant effect (Table 1). The data regarding days to full spike opening in response to calcium sources and its application methods are shown in Table 2. The average data for two years pertaining to application of calcium from various sources showed that the maximum days to full spike opening (11.081 days) were recorded in spikes treated with calcium chloride. The least days to full spike opening (7.216, 7.275 days) were recorded in control treatment (distilled and tape water). The two years mean data regarding application methods revealed that spikes placed in holding solution took more days (9.358) as compared to 8.642 days with foliar applied calcium to the spikes.

The first floret and full spike opening is an important factor in vase life estimation. Significant differences were observed in days to florets opening in spike of gladiolus in response to treatment of various sources of calcium and their application methods. Generally, floret opening took more days in spikes treated with calcium chloride as compared to other sources of calcium. The openings of florets in spike not only add to their aesthetic and market value, but also indicate that the flowers are approaching senescence (Van Doorn, 2004). Therefore, delay in flower opening results in an improved vase life of cut flowers (Anjumet al., 2001). It is reported that flower opening results from developmental events in a typical and defined sequence (Kumar et al., 2008). Calcium, thus, seems to delay the natural development of gladiolus florets toward senescence (Sairam et al., 2011). The calcium is generally applied as calcium chloride because of its relatively high absorption capacity (Lester and Grusak, 2004). The results are in agreement with Anjum et al.,(2001) who reported that florets opening took more time in spikes of tuberose when placed in holding solution of calcium chloride. Delay in floret opening in spikes treated with calcium chloride is also supported by delay in floret fading with the same treatment resulting in retaining the quality of gladiolus spikes as compared to control treatments.

Days to 1st floret fading

Statistical analysis of the data indicated that calcium sources and calcium application methods as well as their interaction significantly affected 1st floret fading of gladiolus spikes (Table 1). The data concerning days to 1st floret fading are presented in Table 2.

Table 1.Mean squares for Days to 1st floret opening(DFO), days to full spike opening (DFSO), days to 1st floret fading(DFF) and days to full spike fading (DFSF) of gladiolus as affected by various sources of calcium and application methods.

SOV	DF	DFO	DFSO	DFF	DFSF
Year	1	0.00 ^{NS}	4.95^{NS}	0.012^{NS}	0.37^{NS}
Appl. Methods (M)	1	0.17*	9.230*	3.627**	7.73**
Ca Sources (S)	5	1.6**	27.3**	6.5**	24.9**
M XS	5	0.06*	2.06^{ns}	0.23**	1.05**
MxY	1	0.004 ^{NS}	1.161 ^{NS}	0.023 ^{NS}	0.29 ^{NS}
SxY	5	0.008 ^{NS}	1.167 ^{NS}	0.154*	0.044 ^{NS}
MxSxY	5	0.011 ^{NS}	1.104 ^{NS}	0.071 ^{NS}	0.017 ^{NS}
Error	48	0.021	1.483	0.052	0.138

NS = Non-significant
*= Significant at P≤0.05
**= Significant at P≤0.01

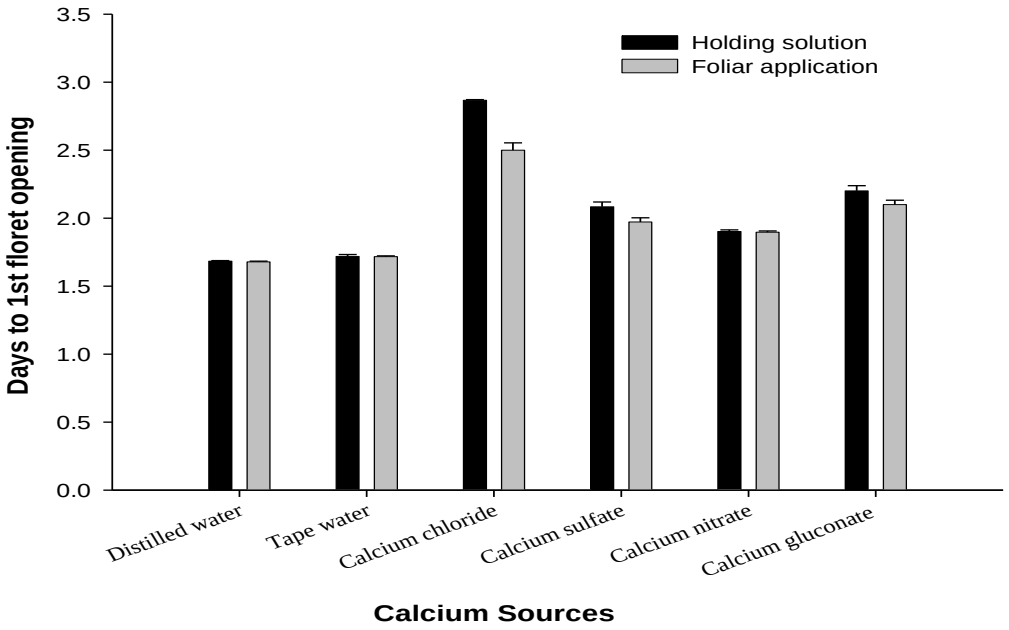


Figure.1 Effect of calcium sources and application methods on days to 1st floret opening. The vertical bars represent standard error (SE) at P≤0.05.

The mean data for two years regarding calcium sources revealed that the maximum days to 1st floret fading (7.394 days) was recorded in spikes of gladiolus treated with calcium chloride, followed by (6.318 days) with calcium gluconate. By contrast, the least days to 1st floret fading (5.383) were recorded in spikes treated with distilled water. The average data for application methods over two years revealed that an early fading of 1st floret (5.837 days) was observed in spikes treated with foliar spray of calcium as compared to 1st floret fading (6.286 days) in spikes placed in holding solutions of calcium. The interaction between calcium sources and calcium application methods (Figure 2), indicated that in both application methods, it took maximum days to 1st floret fading in gladiolus spike treated with calcium chloride, followed by calcium gluconate and calcium sulfate. Among, the calcium sources the earliest 1st floret fading was recorded when spikes were treated with calcium nitrate. However, the least days to 1st floret fading were recorded in spikes treated with foliar applied distilled water.

While the maximum days to 1st floret fading was recorded with calcium chloride treatment in both application methods, however the delay in 1st floret fading was more (8.17%) in spikes treated through holding solution of calcium chloride as compare to spikes sprayed with calcium chloride (Figure 2).

Days to full spike fading

Statistical analysis of the data showed that significant differences were found in days to full spike fading of gladiolus spike in response to calcium sources and application methods as well as their interaction (Table 1). The data regarding days to full spike fading as affected by calcium sources and its application methods are presented in Table 2. It is evident from the average data of calcium sources that a highly significant delay in full spike fading (14.723 days) of gladiolus was observed with treatment of calcium chloride, followed by (13.791 days) in spikes treated with calcium gluconate. Early fading of full spike (11.099 and 11.219 days) was recorded in spikes treated with distilled and tape water respectively. The two years average data for application methods revealed that full spike fading took the maximum days (13.144) in spikes kept in holding solution of calcium as compared to 12.489 days in spikes treated with calcium as a foliar spray. The mean data pertaining the interaction between Calcium sources and application methods (Figure 3) indicated that maximum days to full spike fading were recorded with treatment of calcium chloride, followed by calcium gluconate and calcium sulfate in each method. However, comparing the application methods, the days to full spike fading were more with calcium chloride application through holding solution as compared to foliar application method (Figure 3).

The fading of first floret as well as full spike indicates that the florets have developed to the advanced stage of senescence (Jones et al., 1993). The calcium sources and its application methods resulted in significant variations in days to first floret and full spike fading. It is evident that the days to fading of 1st floret and full spike of gladiolus were more with application of calcium chloride in holding solution. The calcium is regarded as anti-senescence nutrient because it slows down the rate of respiration. Besides, respiration, the calcium regulates and delays senescence by enhancing the activity of antioxidant enzymes (Hepler, 2004; Sairam et al., 2011) and reduces the reactive oxygen species (Leshem, 1992; Paliyath and Droilldard, 1992; Torre et al., 1999; Rubinstein, 2000; Agarwal et al., 2005; Nan, 2007) that results in stabilizing the cell membrane. Thus, calcium slows down the processes that lead to aging or senescence (Kou et al., 2014). While calcium applied from different sources have been reported to delay fading and senescence (Mengel, 2002; Lester and Grusak, 2004). Calcium chloride was most effective in delaying the flower fading (Anjum et al., 2001).

Calcium Sources and Application Methods in Relation to Physical Features

Fresh Floret weight (g)

The statistical analysis of the data indicated that fresh floret weight of gladiolus spike was significantly affected by calcium levels and application methods as well as their interaction (Table 3). The mean data regarding the influence of calcium sources and application methods on the fresh floret weight is given in Table 4. The mean data for various sources of calcium revealed that fresh floret weight was the highest (8.86 g) in gladiolus spikes treated with calcium chloride, followed by (8.115 g) with the application of calcium gluconate. By contrast, the least fresh floret weight (7.341 g) was observed in control (treatment with distilled water). The mean data for application methods showed that holding solution resulted in higher fresh floret weight (8.105 g) as compared to fresh floret weight (7.780 g) with foliar application method. The interaction data of calcium sources and application methods (Figure 4a) indicated the highest fresh floret weight (9.36 g) in spikes kept in holding solution of calcium chloride, followed by (8.36 g) with foliar applied calcium chloride. The minimum fresh floret weight (7.33 g) was recorded with foliar application of distilled water.

Senesced floret weight (g)

The statistical analysis (Table 3) showed that senesced floret weight was significantly affected by different sources of calcium and calcium application methods as well as their interaction. The data pertaining to senesced floret weight of gladiolus as influenced by various sources of calcium and calcium application methods are given in Table 4.

Table 2: Days to 1st floret opening(DFO), days to full spike opening (DFSO), days to 1st floret fading(DFF) and days to full spike fading (DFSF) of gladiolus as affected by various sources of calcium and application methods.

Treatments		Phenological Development of Gladiolus Floret and Spike			
		DFO	DFSO	DFF	DFSF
Calcium sources (S)	Distilled water	1.681e	7.216e	5.383e	11.099e
	Tape water	1.718e	7.275e	5.629d	11.219e
	Calcium chloride	2.683a	11.081a	7.394a	14.723a
	Calcium sulfate	2.028c	9.842c	6.050c	13.358c
	Calcium nitrate	1.899d	9.267d	5.592d	12.708d
	Calcium gluconate	2.150b	9.319b	6.318b	13.791b
	$LSD_{0.05}$	0.119	0.2518	0.188	0.305
Application methods (M)	Holding solution	2.076	9.358	6.286	13.144
	Foliar application	1.977	8.642	5.837	12.489
	Significance	*	*	**	**
Year	Year 1	2.024	8.738	6.048	12.744
	Year 2	2.029	9.262	6.074	12.888
	Significance	NS	NS	NS	NS
Interaction	SxM	* Fig.1	NS	** Fig.2	** Fig.3

NS = Non-significant
*= Significant at P≤0.05
**= Significant at P≤0.01
Means followed by different letters in respective columns are significantly different from each other at P≤0.05.

Table 3.Mean squares for Fresh floret weight (FFW), Senesced floret weight (SFW) and weight loss (WL) of gladiolus spike as affected by various sources of calcium and application methods.

SOV	DF	FFW (g)	SFW (g)	WL (%)
Year	1	0.208^{NS}	0.155^{NS}	0.21^{NS}
Appl. Methods (M)	1	1.906^{**}	8.437^{**}	41.57^{*}
Ca Sources (S)	5	3.3^{**}	25.7^{**}	2208.2^{**}
M xS	5	0.35^{**}	0.76^{**}	5.5867^{**}
MxY	1	0.031^{NS}	0.010^{NS}	0.007^{NS}
SxY	5	0.023^{NS}	0.033^{NS}	0.037^{NS}
MxSxY	5	0.018^{NS}	0.011^{NS}	0.063^{NS}
Error	48	0.066	0.044	0.121

NS = Non-significant
*= Significant at P≤0.05
**= Significant at P≤0.01

Table 4.Fresh floret weight (FFW), Senesced floret weight (SFW) and weight loss (WL) of gladiolus spike as affected by various sources of calcium and application methods.

Treatments		Physical Quality Attributes in Gladiolus Floret and Spike		
		FFW (g)	SFW (g)	WL (%)
Calcium sources (S)	Distilled water	7.341d	3.450e	36.966a
	Tape water	7.549d	3.667d	34.820b
	Calcium chloride	8.860a	6.798a	8.229e
	Calcium sulfate	7.913bc	6.146c	10.328c
	Calcium nitrate	7.877c	6.037c	10.580c
	Calcium gluconate	8.115b	6.394b	9.682d
	LSD $_{0.05}$	0.211	0.173	0.285
Application methods (M)	Holding solution	8.105	5.757	17.674
	Foliar application	7.780	5.073	19.194
	Significance	**	**	*
Year	Year 1 Year 2	7.889 7.996	5.369 5.461	18.381 18.488
	Significance	NS	NS	NS
Interaction	SxM	** Fig. 4a	** Fig. 4b	** Fig.4c

NS = Non-significant
*= Significant at P≤0.05
**= Significant at P≤0.01

Means followed by different letters in respective columns are significantly different from each other at P≤0.05.

The mean data regarding calcium sources showed that the senesced floret weight was the maximum (6.798 g) with the treatment of calcium chloride, followed by (6.394 g) with the application of calcium gluconate. By contrast, the least senesced floret weight (3.45 g) was observed in spikes treated with distilled water. The two years mean data for application methods revealed that senesced floret weight (5.757 g) was higher in spikes held in holding solutions of calcium as compared to (5.073 g) recorded in spikes that received calcium as foliar spray. It is evident from the interaction between calcium sources and application methods (Figure 4b) that calcium chloride in holding solution resulted in the maximum senesced floret weight (7.16 g), followed (6.91 g) with the application of calcium gluconate in holding solution, whereas the least senesced floret weight (3.42 g) was recorded in treatment of spikes with foliar application of distilled water (Figure 4b).

Weight loss (%)

The statistical analysis revealed significant differences in weight loss of gladiolus spike in response to calcium sources and calcium application methods as well as their interaction (Table 3). The data on percent weight loss in gladiolus spikes are presented in Table 4. It is evident from two years average data regarding calcium sources, that the least weight loss (8.229%) was recorded in spikes treated with calcium chloride that increased to 9.682%, 10.328% and 10.580% with the treatment of calcium gluconate, calcium sulfate and calcium nitrate respectively. The control treatment (distilled water) resulted in the highest weight loss (36.966%).The mean data for two years pertaining calcium application methods showed that weight loss of gladiolus spikes (19.194%) was higher in

spikes treated with foliar application of calcium as compared to weight loss (17.674%) observed in spikes present in holding solutions of calcium (Table 3). The mean data regarding interaction between calcium application methods and calcium sources (Figure 4c) revealed that weight loss was the highest (38.55%) in spikes treated with distilled water but declined to the minimum (7.41%) in holding solution of calcium chloride. Though the least weight loss was recorded in spikes treated with calcium chloride through both methods, however weight loss was less in spikes placed in holding solution of calcium chloride (7.41%) as compared 9.05% weight loss recorded in spikes treated with calcium chloride as a foliar spray (Figure 4c).

Flower weight is among the main qualitative factors that determines the freshness, appearance and vase life in cut flowers (Saeedet al., 2013). The weight of fresh florets is due to water balance, which is determined by optimum uptake of water and moisture loss (Ichimura et al., 2006). The calcium treatment and application method resulted in significant differences in the fresh and senesced floret weight in gladiolus spikes. In a similar study, treatment of rose cut flowers with calcium chloride in holding solution was found to increases flower weight (Mortazaviet al., 2007). The flower weight, generally, declines as it advances in senescence (Saks and Staden, 1993) due to water loss (Torre and Fjeld, 2001) and loss of carbohydrates due to respiration; and transpiration (Monteiro et al., 2002; Ezhilmathi et al., 2007). By contrast, treatment that maintains flower weight is also effective in extending the vase life of cut flowers (Cortes et al., 2011). Calcium chloride slows down the metabolism and decreases the weight loss in rose and sunflowers (Torre et al., 1999; Nan, 2007). The rate of respiration and transpiration, and hence water loss, decrease with calcium application in cut flowers (Torre et al., 1999; Hernández-Muñoz et al., 2006; Hatamzadeh et al., 2012). This may explain the observation that the fresh and senesced floret weight was the maximum in spikes placed in holding solution of calcium chloride as compared to the same calcium salt given as foliar spray. Since, calcium regulates physiological processes such as respiration and transpiration and, therefore, decrease the water loss (Anjum et al., 2001; Nan, 2007; Angeletti et al. 2010; Cortes et al., 2011), it is effective measure to decrease the weight loss (Akhtar et al., 2010; Mahajan and Dhatt, 2004).

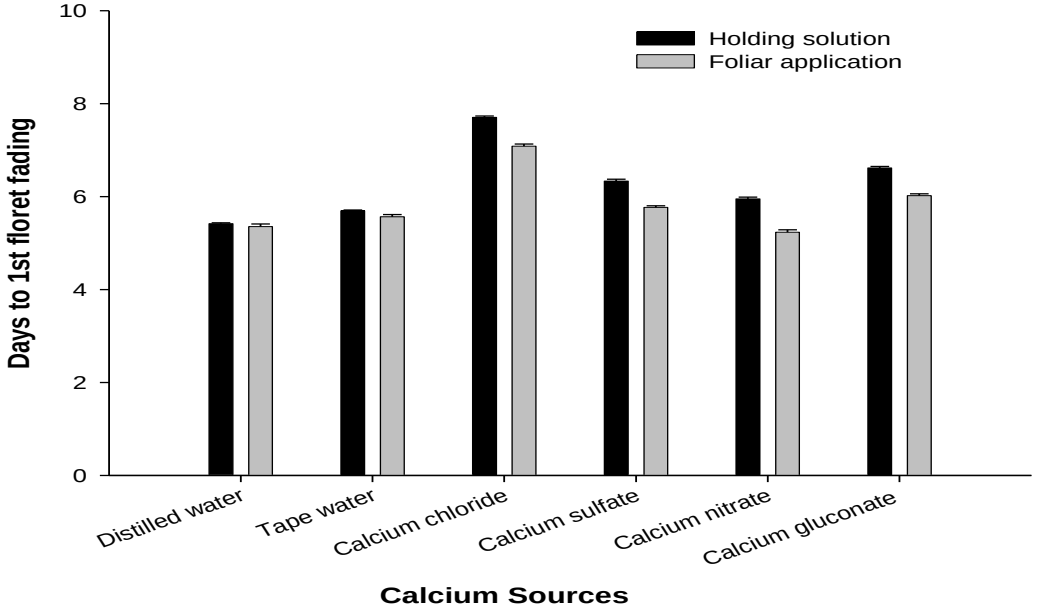


Figure 2: Effect of calcium sources and application methods on days to 1st floret fading. The vertical bars represent standard error (SE) at P≤0.05.

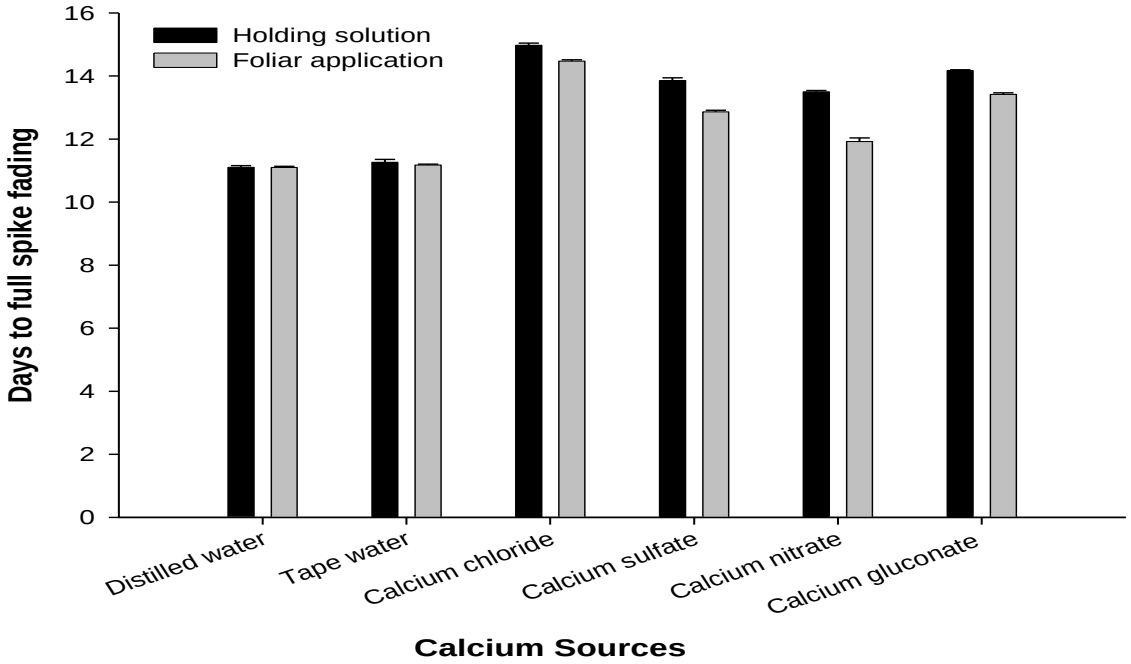
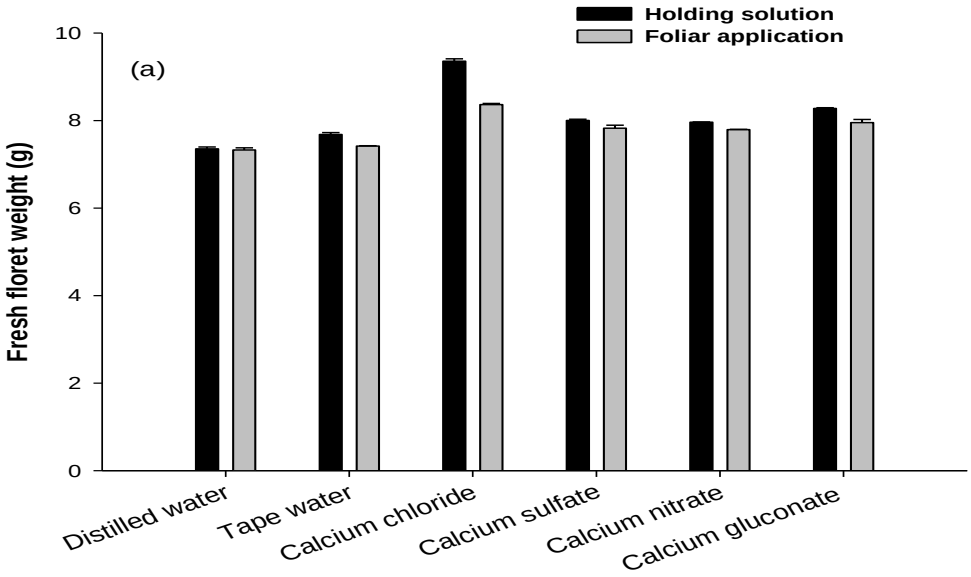


Figure. 3 Effect of calcium sources and application methods on days to full spike fading. The vertical bars represent standard error (SE) at P≤0.05.



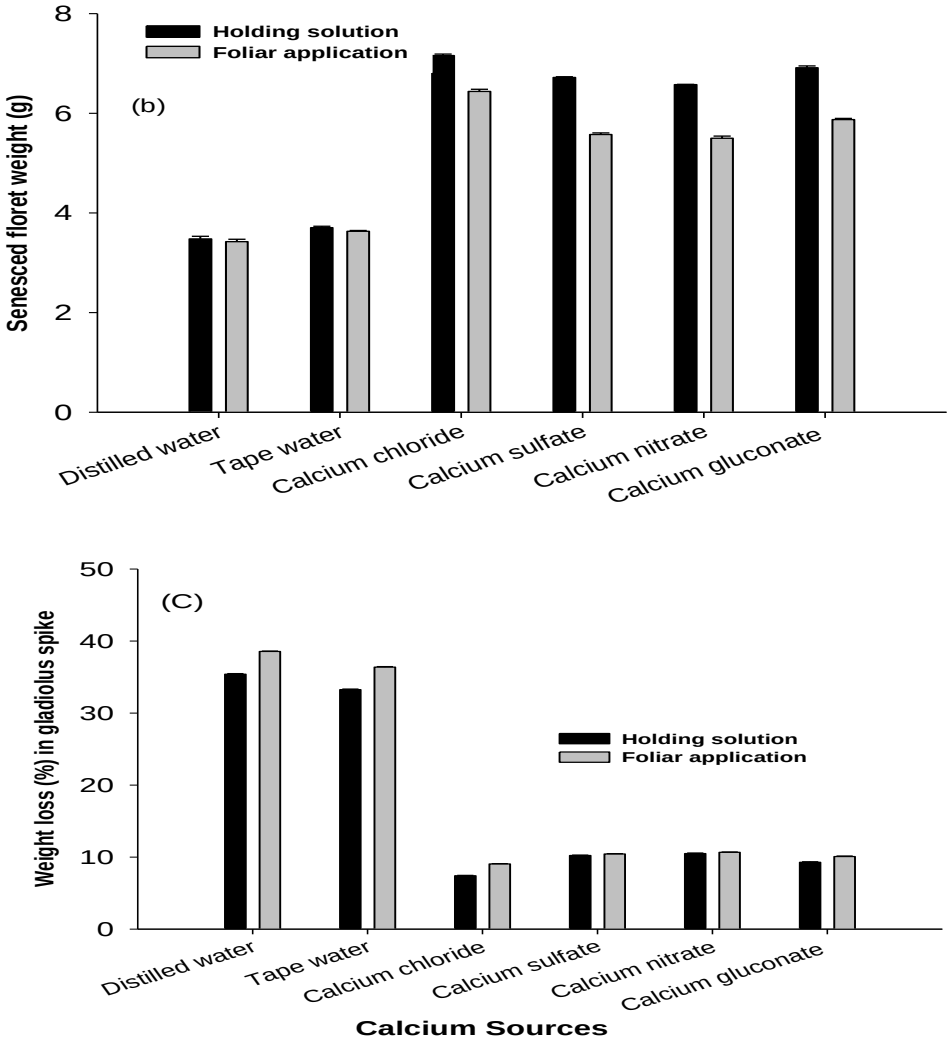


Figure. 4Effect of calcium sources and application methods on (a) fresh floret weight (b) senesced floret weight and (c) weight loss of gladiolus spike. The vertical bars represent standard error (SE) at P≤0.05.

In a similar studies, Torre et al., (1999) and Van Meeteren et al., (1999) reported significant decline in weight loss of cut flowers in roses and other ornamental plants with calcium application.

CONCLUSION

Among various sources of calcium, calcium chloride was found the best source of calcium. Treatment of gladiolus spikes with calcium chloride resulted in delayed opening and fading of florets and spike with highest fresh and senesced floret weight as well as least weight loss of gladiolus spikes. In post-harvest treatment methods, holding solutions of calcium in vase were found superior as compared to foliar application of calcium on spikes. Interaction between calcium sources and post-harvest application methods revealed that holding solutions of calcium chloride significantly improved most of the phenological and physical post-harvest attributes of gladiolus spikes cv. White prosperity. The post-harvest application of calcium chloride as best source of calcium through holding solution is recommended for retention of phenological and physical quality attributes of gladiolus florets and spikes over extended period during marketing.

CONFLICT OF INTEREST

The present study was performed in absence of any conflict of interest. It has not been submitted to any other journal, in whole or in part,

by me or another person. I understand the ethical implications of my research.

ACKNOWLEGEMENT

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AUTHOR CONTRIBUTIONS

Both the authors have contributed: MA conducted experiment, data collection, data analysis and writing of the manuscript. AR supervised the whole research and provided assistance in technical writing of this manuscript. All authors read and approved the final version.

REFERENCES

Agarwal, S., Sairam, R. K., Srivastava, G. C., Tyagi.A and Meena. R. C. 2005. Role of ABA, salicylic acid, calcium and hydrogen peroxide on antioxidant enzymes induction in wheat seedlings. Plant Sci. 169(3): 559-570.

Akhtar, A., Abbasi. N.A and Hussain. A. 2010. Effect of calcium chloride treatments on quality characteristics of loquat fruit during storage. Pak. J. Bot. 42(1): 181-188.

Angelettib.P.,Castagnasso.H., Miceli. E., Terminiello. L., Concellón. A., Chaves. A and Vicentea A.R. 2010.Effect of preharvest calcium applications on postharvest quality, softening and cell wall degradation of two blueberry (*Vacciniumcorymbosum*) varieties.Post-harvest Biol. & Technol. 58: 98-103.

Anjum, M. A., Farrukh .N.,Fariha .S and Shazia. A. 2001. Effect of some chemicals on keeping quality and vase life of tuberose (*Polainthestuberosa L*.) cut flowers. J. Res. 12 (1): 1-7.

Anonymous, 2015.Gladiolus cultivation in Pakistan.http://www.greenworks.com.pk/ gladiolus-cultivation-in-pakistan/ accessed on June 10, 2018.

Beura, S., Ranvir.S., Beura.S and Singh. R. 2001. Effect of pulsing before storage on post-harvest life of gladiolus. J. Ornamental Hort. 4: 91-94.

Bhujbal, G. B., Chavan. N. G. and Mehetre. S. S. 2013. Evaluation of genetic variability heritability and genetic advances in gladiolus (*Gladiolus grandiflorus* L.) genotypes. The Bioscan, 8(4): 1515-1520.

Borochov, A. and Woodson R. W.1989.Physiology and biochemistry of flower petal senescence.Hort. Rev. 11:15-43.

Capdeville, G. D., Maffia. L. A., Finger .F and Batista.U. G. 2005. Pre-harvest calcium sulfate applications affect vase life and severity of gray mold in cut roses. Sci. Hort. 103: 329–338.

Da Silva, J.A.T. 2003. The cut flower: postharvest considerations. J. Biol. Sci. 3(4): 406-442. Easterwood, G.W. 2002.Calcium's role in plant nutrition. Fluid .J. 1: 1-3.

Faraji, S., Naderi. R., Ibadli.O.V.,Basaki .T., Gasimov .S.N. and Hosseinova. S. 2011. Effects of post harvesting on biochemical changes in Gladiolus cut flowers cultivars 'White Prosperity'. Middle-East J. of Sci. Res. 9(5): 572-577.

Ferguson, I.B., 1984. Calcium in plant senescence and fruit ripening. Plant, Cell & Environment, 7(6): 477-489.

Halevy, A.H. 1976. Treatments to improve water balance of cut flowers. Acta Hort. 64:223-230.

Hepler, P.K. 2004. Calcium: A central regulator of plant growth and development. Plant Cell 17: 2142–2155.

Itzhaki, H., Borochov. A and Mayak, S. 1990. Age-related changes in petal membranes from attached and detached rose flowers. Plant physiology, 94 (3): 1233-1236.

Jones, R.B., Serek. M and Reid M.S. 1993. Pulsing with Triton X-100 improves hydration and vase life of cut sunflowers (*Helianthus annuus*L.). Hort Science, 28(12): 1178-1179.

Kou, L., Yang.T.,Luo.Y., Liu. X., Huang L and Codling.E. 2014. Pre-harvest calcium application increases biomass and delays senescence of broccoli microgreens. Postharvest Biol. &Technol. 87: 70-78.

Kumar, N., Srivastava. G.C and Dixit.K. 2008. Flower bud opening and senescence in

roses (*Rosa hybrida L.*). Plant Growth Regulation. 55(2):81.

Lepcha, B., Nautiyal. M.C and Rao.V.K.2007.Variability studies in gladiolus under mid hill conditions of Uttarakhand. J. Ornamental Hort.10(3): 169–172.

Leshem, Y.Y. 1992. Plant membrane: A biophysical approach to structure, development and senescence. Kluwer Acad. Pub. Dordrecht. ISBN 0-7923-1353-4.

Lester, G.E and Grusak.M.A. 2004. Field application of chelated calcium: postharvest effects on cantaloupe and honeydew fruit and quality. Hort. Technol. 14(1): 29-38.

Liemt. G. V. 1999. The world cut flower industry: Trends and prospects, Geneva, Int. Labour Off. (ILO).

Malakouti, M. J. 2003. Balanced fertilization as the most effective and the easiest way for improving the yield and quality of ornamental and cut flower in Iran.Proceedings of the Applied-Scientific Seminar on Flowers and Ornamental Plants, Mahallat National Reseach Center of Ornamental Plants. (2nd: Mahallat, Iran).

Manganaris, G. A., Vasilakakis. M., Diamantidis.G and Mignani. I.2007. The effect of postharvest calcium application on tissue calcium concentration, quality attributes incidence of flesh browning and cell wall physicochemical aspects of peach fruits. Food Chem. 4: 1385-1392.

Mengel, K. 2002. Alternative or complementary role of foliar supply in mineral nutrition.Acta Hort. 594: 3348.

Mortazavi, S.N., Bagheri. F and Bahadoran. M. 2016. Some characteristics of tuberose as affected by pre-harvest application of calcium chloride and gibberillic acid. Adv. Hort. Sci. 30(2): 69-74.

Nan, S.J.S. 2007.Effects of pre- and postharvest calcium supplementation on longevity of sunflower (*Helianthus Annuus* cv. Superior Sunset).(Diss). B.S., xc Louisiana State University. 17-18.

Paliyath, G. and Droilldard. M.J.1992. The mechanism of membrane deterioration and disassembly during senescence. Plant Physiol. Biochem. 30: 789-812.

Ramzan, A., Hafiz, I.A., Ahmad. T and Abbasi. N.A.2010. Effect of priming with potassium nitrate and dehusking on seed germination of gladiolus. Pak. J. Bot. 42(1): 247-258.

Reddy, A.G and Sarkar. M. M. 2016. Studies on the effect of foliar application of calcium on post-harvest, corm and cormel production in gladiolus cv. summer sunshine. Int. J. Agric. Environ. Biotechnol. 9(1): 89.

Riaz, T., Khan S.N and Javaid. A. 2007. Scenario of gladiolus production in Punjab, Pakistan. Pak. J. Bot. 39: 2389-2393.

Rubinstein, B. 2000.Regulation of cell death in flower petals.*Plant Mol. Biol.* 44:303-318.

Sadasivam, S and Manickam. A. 1992. In: Biochemical methods for agricultural sciences. Wiley Eastern Limited, New Delhi.26-27.

Saeed. T., Hassan. I., Abbasi. N.A and Jilani.G. 2013b. Effect of gibberellic acid on the vase life and oxidative activities in senescing cut gladiolus flowers. Springer.

Saeed.T., Hassan. I., Jilani.G and Abbasi. N. A.2013a. Zinc augments the growth and floral attributes of gladiolus, and alleviates oxidative stress in cut flowers. *Sci. Hort.* 164: 124-129.

Sairam, R.K., Vasanthan. B and Arora. A. 2011. Calcium regulates gladiolus flower senescence by influencing anti-oxidative enzymes activity. Acta physiol. Plant. 33(5): 1897-1904.

Salunkhe, D.K., Bhat. N.R and Desai.B.B. 2012. Postharvest biotechnology of flowers and ornamental plants.Springer Science & Business Media.

Singh, J., Singh. M., Jain. A., Bhardwaj. S., Singh .A., Singh .D.K., Bhushan. B and Dubey.S.K. 2013. An introduction of plant nutrients and foliar fertilization: a review “Precision farming: a new approach”. Daya Publishing Co., New Delhi: 252-320.

Tobias, R.B., Conway.W.S.,Sams. C.E., Gross. K.C and Whitaker.B.D.1993. Cell wall composition of calcium treated apples inoculated with *Botrytis cinerea*. Phytochem. 32. 35-39.

Torre, S., Borochov.A and Halevy.A. 1999. Calcium regulation of senescence in roses. *Physiol. Plant*. 107: 214-219.

Van Doorn, W.G. 2004. Is petal senescence due to sugar starvation? Plant Physiology. 134 (1): 35-42.

Van Doorn. W.G., Schurer.K and De. W.K.1989. Role of endogenous bacteria in vascular blockage of cut rose flower. J. Plant Physiol. 134: 375-381.

Van Hemert, N. 2005. E-business and the Dutch flower industry: A survey for strategic opportunities’. IAMA paper, In Holland Uni. Accessed May1, 2018).

Van Ieperen, W. and Van Gelder.A., 2006. Ion-mediated flow changes suppressed by minimal calcium presence in xylem sap in Chrysanthemum and *Prunuslaurocerasus*. *J. Exp. Bot.* 57: 2743–2750.

Van Uffelen, R.L.M and De Groot.N.S.P. 2005. Floriculture worldwide: production, trade and consumption patterns show market opportunities and challenges. Wageningen Uni. Res.: http://ageconsearch.umn.edu/bitstream.

Woltz, S.S. 2001. The world of gladiolus, NAGC, IJSA.pp.143-9.