

# A comparative study between the effect of storage period and gibberellin on growth, flowering, and bulb production of *Hymenocallis speciosa* Salisb.

**Magdy A. Barsoom, Taghreed E. Eissa\*, Basem A. Allam and Fatma El-Zahra H. El-Tony**

Ornamental Plants and Landscape Gardening Research Department, Horticulture Research Institute, Agricultural Research Centre, Giza, Egypt. \*E-mail: [dr.taghreed.eissa.2019@gmail.com](mailto:dr.taghreed.eissa.2019@gmail.com)

## Abstract

This investigation was conducted at the Ornamental Plants and Landscape Gardening Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt, during the 2022 and 2023 seasons to study the influences of gibberellic acid (GA<sub>3</sub>) and storage periods on vegetative growth, flowering, bulbs productivity, and chemical constituents of *Hymenocallis speciosa* (spider lily) plants. A factorial experiment employing a randomised complete block design (RCBD), with three replicates was conducted over two seasons. The experiment incorporated two primary factors: duration of storage (0, 25, 35, and 45 days) and concentrations of gibberellic acid (0, 50, 100, and 150 ppm). The use of GA<sub>3</sub> at a concentration of 150 ppm and a storage period of 35 days had a positive impact on the growth, flowering, and bulb yield of *Hymenocallis* plants. These results provide significant knowledge for horticulturists and researchers seeking to optimise cultivation methodologies for this particular species, indicating that GA<sub>3</sub> may serve as an efficacious tool for enhancing plant performance under defined storage conditions. Subsequent investigations could examine the prolonged effects of gibberellic acid and its potential applications across diverse environmental contexts.

**Key words:** Spider lily, storage period, gibberellic acid, *Hymenocallis speciosa* Salisb.

## Introduction

*Hymenocallis speciosa* L., often designated as the green-tinged spider lily, is categorized as a flowering bulbous plant. This specific species within the *Hymenocallis* genus is endemic to the northern islands of the eastern Caribbean region. Its primary cultivation is for ornamental applications and associated with the Amaryllidaceae family. Under the climatic conditions prevalent in Egypt, this plant species develops bulbs when subjected to cultivation. The flowering stem length can reach an height of up to fifty centimetres. The lanceolate leaves are distinctively narrow, attaining a length of approximately 50 cm and a width of 7 cm. The typical leaf count does not surpass twenty. A solitary umbel can produce as many as twenty white flowers. During the flowering interval, the petals exhibit a reflexing characteristic (curling backwards), resulting in white flowers with a delicate green tint. The blooming phase occurs during the summer. (Nofal *et al.*, 2014; Barsoom, 2014; Barsoom, 2021). *H. speciosa* serves as a potted horticultural specimen. *Hymenocallis* is a genus of 30-40 species originating from tropical and subtropical Americas, including the summer daffodil, spider flower, and basket flower. *Hymenocallis*, a plant with a delicate membranous structure, is known for its fragrant white flowers. These flowers, resembling spider legs, cluster on stalks 60 cm long and are used in landscaping and pots for ornamental display. They can be cut and loose. *H. speciosa* has a globular bulb with a glaucous hue, substantial leaves, and a scape with a glaucous hue. Its flowers, ranging from 10 to 15, are borne on short pedicels with bracts or spathes. The perianth tube is greenish and approximately 3 to 4 inches long, with the segments often being twice the length (culminating in an overall flower length

of around 9 inches). The cup, approximately 1 inch long, features tooth-free filaments slightly longer than the cup itself. The bulb flourishes and improves in quality with age, contingent upon adherence to appropriate cultivation and repotting methodologies. The foliage remains evergreen and presents an aesthetically appealing appearance. The flowers are distinguished by their fragrant qualities and retain their aromatic characteristics even in a desiccated condition. (Chaithra *et al.*, 2020; Barsoom, 2024).

Plant hormones govern many physiological processes, and applying synthetic growth regulators can potentially enhance the quality and yield of floral specimens. The utilization of plant growth regulators has been associated with increased dry matter accumulation within crops, attributable to the augmented synthesis of carbohydrates resulting from a more proficient photosynthetic performance induced by anatomical modifications. Gibberellins cause delayed senescence in flowers and dormancy in ornamental plants. Gibberellins (GAs) play a crucial role in plant species flowering through various molecular mechanisms, including interaction with transcription factors and chromatin remodelling complexes. Gibberellins are integral to flowering and stem elongation processes, among various other biological functions (Sajjad *et al.*, 2014). GA<sub>3</sub> significantly influences plant morphology, physiology, growth, morphogenesis, germination, seedling growth, and product performance, requiring optimal application, species specificity, and seasonal timing (Chaithra *et al.*, 2020; Barsoom and Attala, 2020; Kumar *et al.*, 2021). Gibberellic acid (GA<sub>3</sub>) plays a significant role in breaking dormancy and promoting sprouting in ornamental bulbs during storage. It acts as a substitute for vernalization, reducing the dormancy period and enhancing sprouting rates across various

bulb species. This effect is achieved by modulating physiological processes such as sugar metabolism and enzyme activity, which are crucial for dormancy release and subsequent growth. GA<sub>3</sub> treatments significantly reduce the dormancy period in lily bulbs. For instance, soaking lily bulbs in 100 mg/L GA<sub>3</sub> for 16 hours shortened the dormancy period from 19-20 weeks to 12-13 weeks (Anisah *et al.*, 2023).

Research indicates that specific temperature, humidity, and atmospheric composition significantly influence the preservation of these bulbs. Bulbs should be stored at low temperatures, typically around -2°C to 4.2°C, depending on the species. Also, Wu *et al.* (2022) observed that the pre-planting treatment should be carried out at temperatures of 10 or 16°C for 40 days for *Ornithogalum dubium* bulbs, while, *Lilium longiflorum* thrives at 4.2°C (Deng *et al.*, 2023). This research explores the impact of varying storage durations and the application of gibberellic acid on the bulb production of *H. speciosa*. The study aims to understand how these factors influence the number of bulbs produced, providing insights that could enhance cultivation practices for this ornamental plant.

## Materials and methods

This work was conducted at the Ornamental Plants and Landscape Gardening Research Dept., Hortic. Res. Inst., ARC. Giza, Egypt, through the two seasons of 2022 and 2023, to investigate the effect of gibberellic acid and storage on growth, flowering, bulb production, and chemical constituents of *Hymenocallis* plants.

**Plant material:** Bulbs circumference of 15-17 cm and a weight of 105-110 g were chosen after the lifting date of March 15<sup>th</sup> across both growing seasons. Following thorough examination and cleaning, bulbs were selected and planted on April 15<sup>th</sup>. Bulbs were systematically positioned in discrete plastic receptacles with a diameter of 30 cm, which were filled with a substrate formulated from a 1:1 (v/v) mixture of clay and sand, weighing approximately 7-7.50 kg, with one bulb designated per receptacle. The physical and chemical properties of the soil utilized are outlined in Table 1.

**Experimental design and treatment:** A factorial experiment with a randomized complete block design (RCBD) with three replicates was conducted across two seasons, with two factors: storage days (0, 25, 35, and 45 days) at 4 C<sup>0</sup> and soaking the bulbs in gibberellic acid concentrations (0, 50, 100, and 150 mg/L) for 24 hours. Each treatment combination was replicated three times. The cultural practices were conducted as needed, including watering and weeding, chemical fertilization (Kristalon at 2 g/L at 21-day intervals), and routine agricultural methods.

### Data recorded

**Vegetative growth and root characteristics:** Plant height (cm), number of leaves/plant, leaf area (cm<sup>2</sup>), fresh weight of vegetative parts/plant (g), root length (cm), and fresh weight of roots (g).

**Flowering characteristics:** Number of days from planting to flowering, flower stem weight (g), flower stem length (cm), flower stem diameter (cm), number of flowers/plant and flower diameter (cm).

**Bulbs and bulblets productivity:** Number of bulbs/ plant, bulb fresh weight (g), bulb circumference (cm), and bulblets

circumference (cm), number of bulblets/pot (bulblets yield) and bulblets fresh weight (g).

**Chemical components:** The total chlorophyll concentrations mg/g f.w. in the leaves were assessed utilizing the methodology delineated by Moran (1982).

**Nitrogen, phosphorus and potassium (%) in new bulbs:** Nitrogen was determined by micro-Kjeldahl apparatus (Blake, 1965), and phosphorus was colourimetrically determined in the acid digested using ascorbic acid methods (John, 1970). Potassium was determined using the flame-photometer (Dewis and Freitas, 1970).

**Total carbohydrates percentage:** The methodologies established by DuBois *et al.* (1956) were employed to quantitatively ascertain the percentage of total carbohydrates present in the bulbs through colourimetric analysis.

**Statistical analysis:** The study used the COSTAT computer program for statistical analyses, including variance analysis, and Duncan's Multiple Range Test for treatment means at a 5% significance level according to Gomez and Gomez (1984).

Table 1. Physical and chemical analyses of the experimental soil before planting (Chapman and Pratt, 1962)

Properties	Values	Properties	Values
Sand	32.20%	Organic matter (%)	1.43
Silt	25.30%	Available N (ppm)	90.8
Clay	42.50%	Available P (ppm)	19.6
Textural class	Clay	Available K (ppm)	255
pH	7.50	Fe	5.3
EC (dSm <sup>-1</sup> ) (1:10)	2.80	Mn	9.0
S.P.	33.8	Zn	5.7
Cations (meq/L)		Cu	3.2
Ca <sup>2+</sup>	5.20	<u>Anions (meq/L)</u>	
Mg <sup>2+</sup>	3.00	HCO <sub>3</sub> <sup>-</sup>	5.40
Na <sup>+</sup>	6.40	Cl <sup>-</sup>	7.60
K <sup>+</sup>	5.30	SO <sub>4</sub> <sup>-2</sup>	6.90

## Results and discussion

**Impact of storage days, gibberellic acid, and their interaction on vegetative growth parameters of *H. speciosa*:** According to the results presented in Tables 2 and 3, the storage days treatment in combination with gibberellic acid produced impressive effects. This combination greatly boosted the spider lily plants' performance, resulting in better vegetative growth characteristics. All the data declared that the interaction of storage days and gibberellic acid (GA) significantly affected vegetative growth parameters (plant height, number of leaves per plant, leaf area (cm<sup>2</sup>), and fresh and dry weights of vegetative growth) in *H. speciosa*. The most pronounced significant values concerning vegetative growth characters were observed due to the interaction between a storage duration of 35 days and the application of gibberellic acid at a concentration of 150 ppm. Research involving ornamental plants revealed that Gibberellins (GAs), a phytohormone, promote stem elongation and can increase plant height by 15-30%. The optimal storage duration depends on GA concentration and conditions. Proper management of GA application and storage parameters is crucial for optimal growth.

Extended storage durations can negatively impact growth responses, with studies showing negative impacts on leaf extension rates. Shorter storage durations result in earlier sprouting and enhanced growth, while GA<sub>3</sub> application positively influences plant growth traits (Khan *et al.*, 2013; Bhat and Sheikh, 2015). Furthermore, *Freesia refracta*, combining cold storage with a 200 ppm GA<sub>3</sub> spray, improved morphological and physiological attributes (El-Bably, 2016). This is also in line with a previous study that confirmed that GA<sub>3</sub> effects can vary across species, and the duration of storage before GA application influences plant responsiveness and physiological state (Edrisi and Mirzaei, 2017; Chaithra *et al.*, 2020; Lacerda *et al.*, 2022).

Table 2. Effect of storage periods, gibberellic acid and their interaction on plant height (cm) and number of leaves/plant of *H. speciosa* during the two seasons (2022 and 2023)

GA <sub>3</sub> (A)	Storage period in days (B)									
	Plant height (cm)					Number of leaves/ plant				
	Control	25	35	45	Mean B	Control	25	35	45	Mean B
Season 1										
Control	27.66i	33.33ghi	36.66efg	31.66hi	32.33D	8.44h	10.00gh	10.50cdef	9.50efg	9.70D
50 ppm	32.83fgh	35.33efg	48.00b	32.66fgh	37.20C	10.70fgh	11.76bcd	12.00def	11.40bcd	11.57C
100 ppm	38.00de	42.00d	48.00b	40.00def	42.00B	12.10def	13.00cde	14.00bcd	12.40cdef	12.87B
150 ppm	42.00d	46.00c	51.00a	43.00d	45.5A	14.00bcd	15.00ab	16.30a	14.20bc	14.87A
Mean A	35.13C	39.16B	45.19A	36.83BC		11.31D	12.44B	13.30A	11.88C	
Season 2										
Control	33.33i	36.33gh	37.03gh	35.33i	35.51D	9.00g	11.00def	11.50fg	10fg	10.38D
50 ppm	37.33gh	42.33f	46.33e	38.66g	41.16C	10.25fg	12.50ef	13.50bc	11.50fg	11.94C
100 ppm	43.00f	47.66de	53.00cd	45.50e	47.29B	12.50ef	13.50de	14.50ab	12.50ef	13.25B
150 ppm	49.33f	53cd	56.66a	51.33c	52.58A	15.50bc	14.50cd	16.50a	14.00de	15.13A
Mean A	40.75D	44.83B	48.26A	42.70C		11.81C	12.88B	14.00A	12.00C	

Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

Table 3. Effect of storage periods, gibberellic acid and their interaction on leaf area (cm<sup>2</sup>) and fresh weight of vegetative parts/plant (g) of *H. speciosa* Salisb during the two seasons (2022 and 2023)

GA <sub>3</sub> (A)	Storage period in days (B)									
	Leaf area (cm <sup>2</sup> )					Fresh weight of vegetative parts/plant (g)				
	Control	25	35	45	Mean B	Control	25	35	45	Mean B
Season 1										
Control	88.80o	98.50m	110.25j	91.16n	97.18D	75.20n	87.40m	91.12l	79.16n	83.22D
50 ppm	101.49l	122.48g	137.84c	105.12k	116.73C	100.14k	129.87h	145.78g	125.90j	125.42C
100 ppm	115.12i	132.87e	147.84b	120.20h	129.01B	125.87j	155.90e	165.89d	129.98h	144.41B
150 ppm	125.83f	135.83d	158.40a	135.52d	138.90A	154.34f	182.87b	190.56a	178.90c	176.67A
Mean A	107.81D	120.42B	138.58A	113.00C		113.89D	136.95B	148.34A	130.54C	
Season 2										
Control	105.83l	118.34k	132.05f	112.00m	117.06D	85.98n	93.98l	100.09k	89.76m	92.45D
50 ppm	117.90k	125.38h	143.60d	120.56ij	126.86C	109.34j	124.56i	135.98g	122.89i	123.19C
100 ppm	123.20hi	130.88g	158.96b	144.06d	139.28B	126.90i	142.00f	156.98d	130.15h	139.76B
150 ppm	140.85e	158.40b	168.56a	149.06c	154.22A	160.08c	179.08b	194.78a	164.00e	173.96A
Mean A	121.95C	133.25B	150.79A	131.42B		120.58D	131.15B	147.71A	129.66C	

Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

**Root parameters:** Data in Table 4 show that the interaction of storage duration and gibberellic acid produced the longest root length and heaviest fresh weight of roots in two seasons. GA<sub>3</sub> at 150 ppm significantly affected plant growth, particularly in root development, when paired with 35 storage days. This interaction can optimize the agricultural growth conditions. On the other side, the shortest root was recorded in control in both seasons. Also, Table 4 showed that the application of gibberellic acid (GA) has demonstrated the potential to alleviate the adverse effects of extended storage on root fresh weight (g) at 150 ppm and 35 storage periods as compared with control in two seasons, respectively. Our research suggests that gibberellic acid (GA) enhances growth parameters and root traits, potentially countering storage declines, influencing root weight and morphology, and guiding breeding strategies for responsive cultivars. Research shows that gibberellic acid (GA) at 100 ppm significantly improves root characteristics in ornamental plants. The interaction between storage periods and GA<sub>3</sub> can predict root length, optimizing agricultural growth conditions and influencing GA<sub>3</sub> treatment efficacy. Optimal GA concentrations enhance root length and plant vigour, essential for breeding programs. GA promotes hormonal balance and metabolic pathways, requiring

precise calibration for optimal results (Khan *et al.*, 2013). In other words, GA promotes hormonal balance and metabolic pathways, requiring precise calibration for optimal results (Ge *et al.*, 2023)

#### Parameters of flowering:

Data executed in Tables 5, 6 and, 7 elucidated that all storage periods and gibberellic acid (GA) concentrations significantly affected all flowering parameters (number of days from planting to flowering, flower stem weight, flower stem length (cm), flower stem diameter (cm), number of flowers/plant and flower diameter (cm)). The interaction of storage duration at 35 days and gibberellic acid (GA<sub>3</sub>) application at 150 ppm significantly increased all *H. speciosa* flowering parameters, compared with the control in the two seasons, respectively. This increment may be due to gibberellic acid enhancing flower parameters by promoting cell elongation and division, influencing water absorption, and enhancing vegetative growth and biomass accumulation in plants, influenced by storage duration. These results agree with research indicating that gibberellic acid (GA) and storage conditions significantly impact ornamental plant growth and flowering. GA application enhances flowering in spider lily, gladiolus, Dutch Iris, and Freesia. Ideal GA concentration and

Table 4. Effect of storage periods, gibberellic acid and their interaction on root length (cm) and roots fresh weight (g) of *H. speciosa* during the two seasons (2022 and 2023)

GA <sub>3</sub> (A)	Storage period in days (B)									
	Root length (cm)					Roots fresh weight (g)				
	Control	25	35	45	Mean B	Control	25	35	45	Mean B
Season 1										
Control	32.66m	46.00jk	49.00hi	40.00l	41.91D	86.00m	95.00k	108.00jk	90.00l	94.75D
50 ppm	41.33k	51.33e	56.00d	44.00k	48.17C	95.00k	155.00f	167.00d	129.00i	136.5C
100 ppm	48.00ij	52.50ef	59.00c	51.00fgh	52.63B	110.00j	160.00e	176.00b	147.00g	148.25B
150 ppm	50.00ghi	55.33b	69.00a	52.00efg	56.58A	137.00h	177.00c	190.00a	159.00e	165.75A
Mean A	43.00D	51.29B	58.25A	46.75C		107.00D	146.75B	160.25A	131.25C	
Season 2										
Control	36.00i	47.00h	50.00g	45.00hi	44.50D	97.00p	102.00n	110.00l	100.00o	102.25D
50 ppm	44.66fg	52.00fg	57.00cd	47.00h	50.16C	107.00m	140.00h	169.00d	131.00j	136.75C
100 ppm	51.00fg	53.00ef	60.00ab	52.00fg	54.00B	112.00k	167.00e	182.00b	149.00g	152.50B
150 ppm	52.66cd	59.00bc	62.00a	55.00de	57.16A	139.00i	176.00c	192.00a	161.00f	167.00A
Mean A	46.08D	52.75B	57.25A	49.75C		113.75D	146.25B	163.25A	135.25C	

Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

Table 5. Effect of storage periods, gibberellic acid and their interaction on the number of days from planting to flowering and flower stem weight (g) of *H. speciosa* during the two seasons (2022 and 2023)

GA <sub>3</sub> (A)	Storage period in days (B)									
	Number of days from planting to flowering					Flower stem weight (g)				
	Control	25	35	45	Mean B	Control	25	35	45	Mean B
Season 1										
Control	128.73a	126.61b	122.16	125.26c	125.69A	22.67g	26.03g	31.12ef	27.50e	26.83D
50 ppm	124.16cd	122.06de	118.25g	123.60cd	122.02B	25.96e	31.12ef	35.91bc	28.33fg	30.33C
100 ppm	122.73de	120.54ef	116.42gh	118.16g	119.46C	27.63e	37.84d	43.11ab	32.60e	35.30B
150 ppm	120.55ef	118.54fg	110.23i	115.03h	116.09D	34.00e	39.00cd	45.25a	36.66bc	38.73A
Mean A	124.04A	121.94B	116.77D	120.51C		27.57D	33.50B	38.85A	30.77c	
Season 2										
Control	127.52a	119.20d	113.96e	122.28c	120.08A	22.66k	26.70j	31.04gh	29.30hi	27.43D
50 ppm	125.40b	118.50d	107.80fg	119.50d	117.30B	25.29fgh	32.12fg	36.58e	30.33ghi	31.08C
100 ppm	119.50d	114.40e	109.50f	115.40e	114.95C	29.30hi	37.50de	42.77b	34.26f	36.38B
150 ppm	115.80e	107.20fg	105.50g	114.50e	110.75D	33.66f	40.00c	47.58a	34.66cd	38.47A
Mean A	120.89A	114.83C	109.19D	118.17B		27.72D	34.08B	39.49A	32.14C	

Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

application method are species-dependent, emphasizing the need for species-specific optimization (Khan *et al.*, 2013; El-Bably, 2016). This also aligns with findings by Edrisi and Mirzaei (2017); Rahman *et al.* (2019); Sanches *et al.* (2019), who noted that GA<sub>3</sub> directly affects cell wall elongation, increasing stem length. Storage duration and concentration influence growth response. Previous studies show GA<sub>3</sub> treatments increase plant stem weight, with storage duration and application crucial. Also, these results agree with research indicating that higher GA<sub>3</sub> concentrations enhance stem length and vegetative growth, while proper storage conditions and environmental factors can improve growth outcomes, with shorter applications enhancing growth metrics (Patnaik and Nayak, 2020; Chaithra *et al.*, 2020; Basheer and Ali, 2021; Lacerda *et al.*, 2022; Kassem *et al.*, 2022; Ahmadnia, 2024).

**Bulbs and bulblets productivity:** Data listed in Tables 8, 9 and 10 indicated that the storage duration of 35 days and the application of gibberellic acid (GA<sub>3</sub>) at 150 ppm significantly increased all bulbs and bulblets parameters (number of bulbs/plant, bulbs fresh weight (g), bulb circumference (cm), bulblets circumference (cm.), number of bulblets and bulblets fresh weight (g.) in two seasons. Cold storage of bulbs generally accelerates flowering and improves various growth parameters, which is reflected in bulb yields and weights. GA application can break dormancy, promote earlier flowering, and increase stem elongation. However, the effects of GA on bulb yield vary among species, with some showing reduced yield and others increasing yield. This observation is further corroborated by earlier research affirming that cold storage and gibberellic acid (GA) treatment can improve morphological and physiological traits in some species. The optimal storage temperature and duration depend on the species. GA generally enhances growth and flowering, but high concentrations can negatively affect germination and flowering speed (Khan *et al.*, 2013; El-Bably, 2016; Edrisi and Mirzaei, 2017).

The impact of gibberellic acid (GA<sub>3</sub>) on breaking dormancy and promoting sprouting in *Hymenocallis* bulbs during storage is significant. GA<sub>3</sub> stimulates sprouting and shortens dormancy duration in bulb species like lilies and fritillaries, enhancing bulb vitality through physiological changes necessary for sprouting (Anisah *et al.*, 2023)

### Chemical constituents of the leaves

#### Total chlorophyll (mg/g f.w.):

According to data presented in Fig. 1, the interplay between storage duration and the application of gibberellic acid (GA<sub>3</sub>) exerts a significant influence on the biosynthesis of pigments within the foliage, specifically regarding the concentrations of chlorophyll. The study revealed that storage duration and gibberellic acid application significantly impact the biosynthesis of pigments in foliage, especially concerning chlorophyll concentrations. The optimal results were achieved through a 35-day storage period and GA<sub>3</sub> application at 150 ppm, significantly elevated chlorophyll levels across two growing seasons. In marigold, higher concentrations of GA<sub>3</sub> (up to 250 mg L<sup>-1</sup>) resulted in increased chlorophyll a and b, with total pigment content peaking after multiple applications (Sardoo, 2016).

#### Chemical constituents of the newly formed bulbs:

**Minerals % in bulbs:** The study revealed that applying gibberellic acid (GA<sub>3</sub>) significantly increased the concentration of minerals in leaves (N, P, and K) compared to other treatments. The lowest scores were obtained with the control treatment. Gibberellic acid (GA<sub>3</sub>) significantly increased leaves' mineral %,

Table 6. Effect of storage periods, gibberellic acid and their interaction on flower stem length (cm.) and flower stem diameter (cm) of *H. speciosa* during the two seasons (2022 and 2023)

GA <sub>3</sub> (A)	Storage period in days (B)									
	Flower stem length (cm.)					Flower stem diameter (cm)				
	Control	25	35	45	Mean B	Control	25	35	45	Mean B
Season 1										
Control	24.33fg	34.00efg	37.20de	30.50g	31.51D	1.16m	1.30k	1.39j	1.27l	1.28C
50 ppm	28.07ef	37.50de	37.53cd	34.50ef	34.40C	1.66j	2.10e	2.20d	1.80h	1.94B
100 ppm	36.40b	43.93b	53.00a	43.20c	44.13B	1.85g	2.20d	2.30b	1.88f	2.05A
150 ppm	43.20c	48.50b	55.50a	47.50b	48.68A	1.98f	2.28c	2.40a	2.00e	2.17A
Mean A	33.00D	40.98B	45.80A	38.93C		1.66D	1.82B	2.07A	1.74C	
Season 2										
Control	25.49gh	31.83i	40.83f	32.83hi	32.74D	1.17n	1.28m	1.29l	1.30k	1.26D
50 ppm	29.83i	37.00g	44.50e	36.00g	36.83C	1.80i	1.90h	2.20e	1.86j	1.94C
100 ppm	33.50hi	47.50cd	50.50b	45.50de	44.27B	2.00g	2.20e	2.31c	2.10f	2.15B
150 ppm	33.83f	49.00bc	55.00a	48.00c	46.45A	2.10f	2.47b	2.67a	2.30d	2.39A
Mean A	30.68C	41.33B	47.70A	40.58B		1.77D	1.96B	2.12A	1.89C	

Table 7. Effect of storage periods, gibberellic acid and their interaction on the number of flowers/plant and flower diameter (cm) of *H. speciosa* during the two seasons (2022 and 2023)

GA <sub>3</sub> (A)	Storage period in days (B)									
	Number of flowers/plant					Flower diameter (cm)				
	Control	25	35	45	Mean B	Control	25	35	45	Mean B
Season 1										
Control	10.00j	11.50g	12.00f	11.00g	11.13D	19.08g	21.89d	23.98bcd	20.00f	21.24C
50 ppm	11.00i	12.00f	13.56d	11.20f	11.94C	20.76f	23.09cd	24.98abc	22.00e	22.71B
100 ppm	12.00f	12.89e	13.80c	12.20e	12.72B	22.37d	23.91bcd	24.89abc	22.54cd	23.21B
150 ppm	13.00e	15.06b	16.10a	14.00c	14.54A	21.50e	24.90abc	26.90a	25.45ab	24.91A
Mean A	11.50D	12.86B	13.87A	12.10C		20.93D	23.45B	25.19A	22.50C	
Season 2										
Control	8.56e	10.25cd	11.50bcd	10.00cd	10.08C	17.41e	22.33cd	23.48bc	20.09d	20.83D
50 ppm	9.58d	11.55bcd	12.50bc	11.00bcd	11.16BC	19.76e	22.67bcd	23.97bc	21.96d	22.08C
100 ppm	10.50cd	11.51bcd	12.80bc	11.03cd	11.46B	22.37bc	23.81bc	24.19bc	22.50bcd	23.22B
150 ppm	12.54bc	12.57bc	13.98a	12.75b	12.96A	23.70bc	25.26b	26.90a	24.78bc	25.16A
Mean A	10.30C	11.47B	12.70A	11.20B		20.81C	23.52B	24.64A	22.33B	

Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

Table 8. Effect of storage periods, gibberellic acid and their interaction on the number of bulbs/plants and bulb fresh weight (g) of *H. speciosa* during the two seasons (2022 and 2023)

GA <sub>3</sub> (A)	Storage period in days (B)									
	Number of bulbs/plants					Bulb fresh weight (g)				
	Control	25	35	45	Mean B	Control	25	35	45	Mean B
Season 1										
Control	0.93k	1.00k	1.15h	0.98k	1.02D	65.00j	78.09h	82.13g	73.10i	74.58D
50 ppm	1.12i	1.15h	1.23g	1.14i	1.16C	78.00h	85.00fg	88.70ef	84.00g	83.93C
100 ppm	1.27f	1.32c	1.36c	1.29e	1.31B	86.00efg	94.00d	97.60cd	89.90e	91.88B
150 ppm	1.33c	1.98a	2.00a	1.44b	1.69A	98.00c	103.82b	111.30a	100.80bc	103.48A
Mean A	1.16D	1.36B	1.44A	1.21C		81.75D	90.23B	94.93A	86.95C	
Season 2										
Control	0.91k	0.97j	1.00j	1.00j	0.97D	76.12j	85.00gh	90.00f	80.00i	82.78D
50 ppm	1.05j	1.20gh	1.24f	1.18h	1.17C	81.04i	87.00fg	94.70de	84.00hi	85.85C
100 ppm	1.15i	1.32e	1.48c	1.22fg	1.29B	83.08hi	90.00f	98.60bc	86.80fg	89.62B
150 ppm	1.26h	1.64b	1.89a	1.38c	1.54A	91.06ef	99.50b	105.98a	95.33cd	97.97A
Mean A	1.09D	1.28B	1.40A	1.20C		82.83D	90.38B	97.32A	86.53C	

Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

with the most favourable results observed when cold storage for 35 days and GA<sub>3</sub> application at 150 ppm were combined (Figs. 2, 3 and 4). These results are in agreement with Othman *et al.* (2023) on *Chrysanthemum morifolium*, who found that GA<sub>3</sub> at 300 ppm resulted in the highest levels of potassium (K%), phosphorus (P%), total carbohydrates, and chlorophylls.

**Total carbohydrates (%):** The storage duration and gibberellic acid (GA<sub>3</sub>) significantly impact the rate of total carbohydrates accumulation in newly formed bulbs. Extended storage periods can lead to variations in carbohydrate composition, affecting both the quality and growth potential of the bulbs. Data illustrated in Fig. 5 found a significant effect in the overall carbohydrate accumulation in the newly developed bulbs, resulting from 150 ppm GA<sub>3</sub> and subsequent storage for 35 days across both growing seasons. Different authors also reported similar results on different bulb species. Low-temperature storage facilitates the breakdown of starch and enhances sugar accumulation, which is vital for breaking dormancy in bulbs (Vieira *et al.*, 2011; Zhang *et al.*, 2011; Sarkar *et al.*, 2014; and Zhang *et al.*, 2022), while longer storage durations in *Lilium oriental* hybrids increase carbohydrate accumulation but may lead to depletion as bulbs use reserves for growth, indicating a balance between storage duration and carbohydrate management (Kim and Oh, 2021). Also, Yu *et al.* (2022) reported that cold storage leads to starch breakdown and increased sucrose levels, peaking around 60 days. This process is crucial for taste improvement and energy availability for bulb growth.

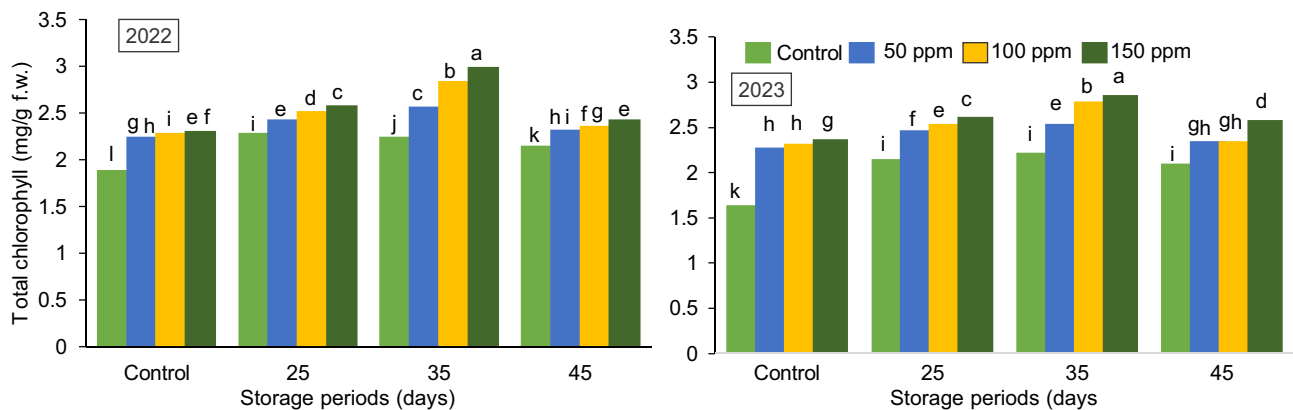
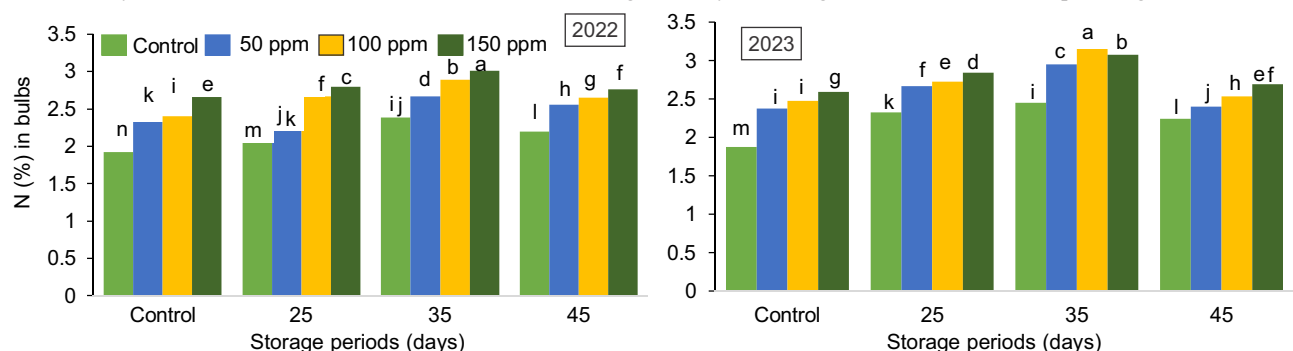
Table 9. Effect of storage periods, gibberellic acid and their interaction on bulb circumference (cm) and bulblet circumference (cm) of *H. speciosa* during the two seasons (2022 and 2023)

GA <sub>3</sub> (A)	Storage period in days (B)									
	Bulb circumference (cm)					Bulblet circumference (cm.)				
	Control	25	35	45	Mean B	Control	25	35	45	Mean B
Season 1										
Control	20.00ef	21.60e	23.67cde	21.45e	21.75D	7.66j	8.35j	10.06ij	8.00j	8.52D
50 ppm	21.54e	24.00cde	24.50abc	23.00de	23.26C	10.53hi	12.00gh	12.37fgh	11.00h	11.48C
100 ppm	22.07e	24.80abc	26.70ab	24.00cde	24.39B	12.10gh	14.51bcd	15.58b	13.60def	13.95B
150 ppm	24.80abc	25.06abc	28.57a	24.60abc	25.76A	13.33efg	15.00bc	18.20a	14.40cde	15.23A
Mean A	22.10C	23.93B	25.86A	23.26B		10.91C	12.47B	14.05A	11.75B	
Season 2										
Control	18.00ef	20.87cdef	21.67cde	20.00def	20.14D	7.51g	8.68f	12.00e	10.09ef	9.57D
50 ppm	19.54def	22.00cde	22.50bcd	20.45def	21.12C	12.01e	14.52d	17.57abc	15.10cd	14.80C
100 ppm	21.07cdef	22.90bcd	24.70b	21.00cdef	22.42B	14.57d	16.57abcd	18.01ab	15.50bcd	16.16B
150 ppm	23.80bc	24.06bc	25.57a	21.60cde	23.76A	16.07ef	17.17abc	19.10a	16.65abcd	17.25A
Mean A	20.60C	22.46B	23.61A	20.76C		12.54C	14.24B	16.67A	14.34B	

Table 10. Effect of storage periods, gibberellic acid and their interaction on the number of bulblets and bulblet fresh weight (g) of *H. speciosa* during the two seasons (2022 and 2023).

GA <sub>3</sub> (A)	Storage period in days (B)									
	Number of bulblets					Bulblets fresh weight (g)				
	Control	25	35	45	Mean B	Control	25	35	45	Mean B
Season 1										
Control	1.35efg	1.50defg	1.87cd	1.60def	1.58C	14.16l	24.00hij	26.33efgh	22.50ij	21.75D
50 ppm	1.78cde	1.89cd	1.90cd	1.80de	1.84B	19.66kl	26.80efgh	28.66def	25.27fghi	25.10C
100 ppm	1.81de	1.90cd	2.00bc	1.85cd	1.89B	22.33jk	29.70de	36.33bc	27.45defg	28.95B
150 ppm	2.00bc	2.07b	2.75a	2.10b	2.23A	31.00d	38.80b	43.50a	35.30c	37.15A
Mean A	1.74C	1.84B	2.13A	1.84B		21.79D	29.83B	33.71A	27.63C	
Season 2										
Control	1.73def	1.79de	2.00cde	1.78de	1.83D	13.33l	22.13jk	28.50f	20.00kl	20.99D
50 ppm	1.92	2.13cde	2.20cd	2.00cde	2.06C	20.66kl	24.40hi	26.50gh	24.50hi	23.67C
100 ppm	2.20cd	2.30c	2.55b	2.18cd	2.31B	25.80j	29.20ef	38.00b	26.80fg	29.95B
150 ppm	2.25c	2.45b	3.05a	2.20cd	2.49A	32.95d	35.77c	42.50a	30.50de	35.43A
Mean A	2.03C	2.17B	2.45A	2.04C		23.19D	27.90B	33.88A	25.09C	

Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

Fig. 1. Effect of storage days, gibberellic acid, and their interaction on the total chlorophyll of *H. speciosa* during the two seasons (2022 and 2023). Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .Fig. 2. Effect of storage days, gibberellic acid, and their interaction on N (%) in bulbs of *H. speciosa* during the two seasons (2022 and 2023). Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

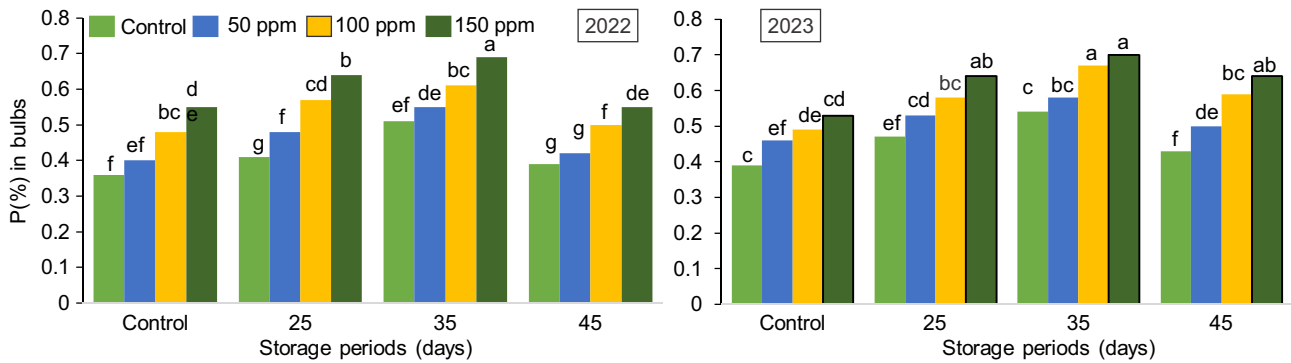


Fig. 3. Effect of storage days, gibberellin acid, and their interaction on phosphorus % in bulbs of *H. speciosa* during the two seasons (2022 and 2023). Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

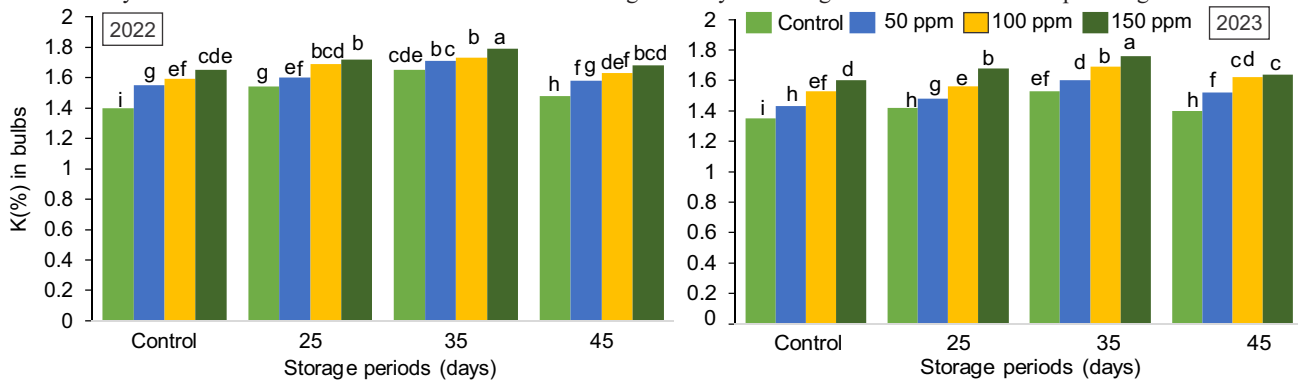


Fig. 4. Effect of storage days, gibberellin acid, and their interaction on K (%) in bulbs of *H. speciosa* during the two seasons (2022 and 2023). Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

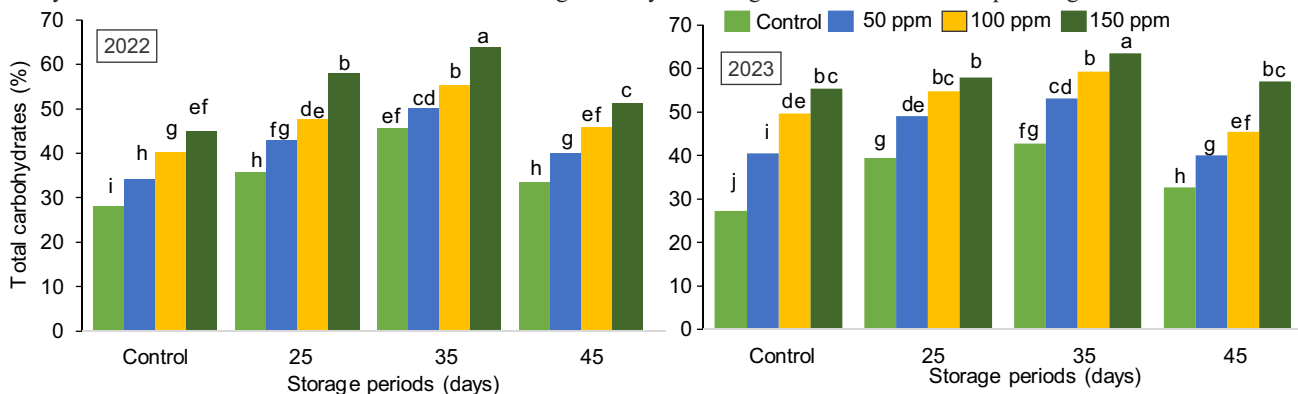


Fig. 5. Effect of storage days, gibberellin acid, and their interaction on total carbohydrates % of *H. speciosa* during the two seasons (2022 and 2023). Means followed by the same letters in a column or row do not differ significantly according to Duncan's New Multiple Range test at  $P = 0.05$ .

In conclusion, applying gibberellin acid at 150 ppm, combined with a storage duration of 35 days, demonstrates a positive effect on the growth, flowering, and bulb productivity of *Hymenocallis* plants. These findings provide valuable insights for horticulturists and researchers aiming to improve the cultivation practices of this species, suggesting that GA<sub>3</sub> can be an effective tool for enhancing plant performance under specific storage conditions.

## Acknowledgments

We are grateful to Prof. Dr. Emam M.S. Nofal, Professor of Floriculture and Ornamental Horticulture at the Horticulture Department, Faculty of Agriculture, Kafr El-Sheikh University, for his invaluable assistance and guidance throughout the manuscript review process.

## References

Ahmadnia, F., M.T. Alebrahim, L. Nabati Souha and D.R. MacGregor, 2024. Evaluation of techniques to break seed dormancy in Redroot pigweed (*Amaranthus retroflexus*). *Food Sci. Nutr.*, 12(4): 2334-2345.

Anisah, S.N., D. Ratnadewi and E.D.J. Supena, 2023. Exogenous gibberellin acid stimulates bulb dormancy breaking and the role of paclobutrazol in maintaining the size of harvested bulb of lily (*Lilium sp.*) cv. Tisento. *Sains Malaysiana*, 52(7): 1967-1976.

Barsoom, M.A. 2014. Physiological studies on some ornamental bulbs. Ph.D. Thesis, Fac. Agric., Kafr El-Sheikh Univ., Egypt.

Barsoom, M.A. and M.A. Attala, 2020. Effect of etrel and gibberellin acid on growth, flowering, sex ratio and yield to luffa plant. *Middle East J. Agric. Res.*, 9(4): 984-993.

Barsoom, M.A. 2021. Comparative study on the effect of organic, bio, chemical fertilization and natural extracts on *Hymenocallis speciosa* response to salinity tolerance. *Int. J. Environ.*, 10 (1): 47-65.

Barsoom, M.A., N.E.S. Abdul-Moneem and E.A. Khella, 2024. Influence of foliar spray with amino acids and seaweed extract combined with microelements and calcium on growth, flowering and yield of *Hymenocallis speciosa* L. *Sci. J. Flowers Ornamental Plants*, 11(3): 175-190.

Basheer, S.A. and S.H. Ali, 2021. Effect of stratification and dipping with different concentrations of gibberellin acid in the vegetative and root growth characteristics of *Pinus eldarica* Medw. *J. Kerbala Agric. Sci.*, 8(2): 12-21.

- Bhat, Z.A. and M.Q. Sheikh, 2015. Studies on chemical solutions and storage duration on keeping quality of cut Gladiolus (*Gladiolus grandiflorus* L.) spikes ('White Prosperity'). *J. Sci. Res. Essays*, 10 (24): 655-658.
- Blake, C.A. 1965. *Methods of Soil Analysis*. Part I and II. Amer. Soc. Agron. in Puhl. Madison. Wise U.S.A.
- Chaithra, P.V., H. Naik, S.Y. Chandrashekar, M. Ganapathi and Y. Kantharaj, 2020. Standardization of plant growth regulators on growth and flowering of spider lily (*Hymenocallis speciosa* L.). *IJCS*, 8(5): 1748-1751.
- Chapman, H. D. and P.F. Pratt, 1962. Methods of analysis for soils, plants and waters. *Soil Sci.*, 93(1): 68.
- Deng, P., K. Li, W. Chen, J. Dai, A. Chen and Yin, L. (2023). Optimisation of the controlled atmosphere storage and shelf life of *Lilium longiflorum*. *Qual. Assur. Saf. Crops Foods*, 15(SP1): 1-15.
- Dewis, J. and F. Freitas, 1970. Physical and chemical methods of soil and water analysis. Food and Agric. Organization of the United Nations of Soils Bulletin, (10): 275.
- DuBois, M., K.A. Gilles, J.K. Hamilton, P.T. Rebers and F. Smith, 1956. Colourimetric method for determination of sugars and related substances. *Anal. Chem.*, 28(3): 350-356.
- Edrisi, B. and S. Mirzaei, 2017. An investigation into the effect of gibberellic acid and storage temperature on vegetative and reproductive characteristics of tuberose (*Polianthes tuberosa*). *J. Ornamental Plants*, 7(2): 137-146.
- El-Bably, S.Z. 2016. Response of *Freesia refracta* (Jacq), plant to corms cold storage, gibberellic acid and their interactions in North Delta, Egypt. *Middle East J. Agric. Res*, 5(4): 507-521.
- Ge, N., J.S. Jia, L. Yang, R.M. Huang, Q.Y. Wang, C. Chen and J.W.Chen, 2023. Exogenous gibberellic acid shortening after-ripening process and promoting seed germination in a medicinal plant *Panax notoginseng*. *BMC Plant Biol.*, 23(1): 67.
- Gomez, K.A. and A.A. Gomez, 1984. *Statistical Procedures for Agricultural Research*. John Wiley and Sons, Inc., New York, pp: 680.
- John, E.B. 1970. Colourimetric determination of phosphorus in soil and plant materials with ascorbic acid. *Soil Sci.*, 109 (4): 214-220.
- Kassem, H. A., H.A. Marzouk, B.M. Almunqedhi and I.El Berry, 2022. Postharvest quality maintenance of 'Crimson Seedless' grapes by preharvest applications. *Acta Scientiarum Polonorum Hortorum Cultus*, 21(1): 79-87.
- Khan, F.N., M.M. Rahman and M.M. Hossain, 2013. Effect of benzyladenine and gibberellic acid on dormancy breaking, growth and yield of gladiolus corms over different storage periods. *J. Ornamental Hortic. Plants*, 3(1): 59-71.
- Kim, J. and W. Oh, 2021. Cold storage period of bulbs influences their sugar contents and post-storage growth and flowering in *Lilium oriental* Hybrids. *Agric.*, 11(11): 1080.
- Kumar, M., V. Chaudhary and U. Sirohi, 2021. Plant growth regulators and their implication in ornamental horticulture: An overview. *Inter. J. Agric., Enviro. Biotech.*, 14(03): 417-445.
- Lacerda, V.R., L.F. Pagehú, A.P. Gonçalves, R.L. Vieites and P.S.N. Lopes, 2022. Gibberellic acid concentrations and storage of *Caryocar brasiliense* (Caryocaraceae) seeds propagated in tubes. *Hortic.*, 8(11): 1094.
- Moran, R. 1982. Formulae for determination of chlorophyllous pigments extracted with N, N-dimethylformamide. *Plant Physiol.*, 69(6): 1376-1381.
- Nofal, E., M.El-Tarawy, A. Nabih, A. El-Ghany and M. Hanan, 2014. Quantifying the most suitable irrigation regime for *Hymenocallis speciosa* Salisb. plant grown in different potting media, under open nursery conditions. *Sci. J. Flowers Ornamental Plants*, 1(3): 199-221.
- Othman, E.Z., R.A. El-Ziat, H.M. Farag and I.M. El-Sayed, 2023. Influence of Gibberellic acid and Methionine on growth, flowering quality, leaf anatomical structure and genetic diversity of *Chrysanthemum morifolium* Ramat plant. *Emir. J. Food Agric.*, 9: 813-825.
- Patnaik, J.R. and P.K.Nayak, 2020. Enhancing cane and sugar productivity applying variable modes of plant growth regulators in sugarcane (*Saccharum* sp. complex) cultivation under coastal climatic conditions of India. *Indian J. Agric. Sci*, 90(11): 2174-2179.
- Rahman, A., G. Nabi, W. Khan, M.N. Khan, M. Hissam, M. Ilyas and Y. Ali, 2019. Influence of gibberellic acid on vegetative, floral and corm yield of Gladiolus cultivars under the agro-climatic condition of Peshawar-Pakistan. *Pure. Appl. Biol.*, 8(1): 559-571.
- Sajjad, Y., M.J. Jaskani, M.Y. Ashraf, M. Qasim and R. Ahmad, 2014. Response of morphological and physiological growth attributes to foliar application of plant growth regulators in gladiolus' white prosperity'. *Pakistan J. Agric. Sci.*, 51(1): 123-129.
- Sanches, A.G., M.B. da Silva, E.g.S. Moreira and C.A.M. Cordeiro, 2019. Maintenance solutions for the conservation of sunflower inflorescences. *Emir. J. Food Agric.*, 31(5): 335-341.
- Sardoo, S.F. 2016. Response of plant growth regulators on leaf photosynthetic pigments of pot Marigold. *World J. Pharmacy Pharmaceutical Sci.*, 5: 198-205.
- Sarkar, M.A. H., M.I. Hossain, A.F.M.J. Uddin, M.A.N. Uddin and M.D. Sarkar, 2014. Vegetative, floral and yield attributes of gladiolus in response to gibberellic acid and corm size. *Sci. Agric.*, 7(3): 142-146.
- Vieira, Y., J. Zhao, W. Lu and D. Deng, 2017. Gibberellin in plant height control: old player, new story. *Plant Cell Reports*, 36: 391-398.
- Wu, X., L.Wang and M. Roh, 2022. Reduction of leaf tip burns of *Ornithogalum dubium* by controlling the temperature during bulb storage and greenhouse forcing to produce quality plants. *Adv. Hortic. Sci.*, 36(1): 3-11.
- Yu, J., S. Xu, X. Liu, T. Li, D. Zhang, N. Teng and Z. Wu, 2022. Starch degradation and sucrose accumulation of lily bulbs after cold storage. *Int. J. Mol. Sci.*, 23(8): 4366.
- Zhang, X., B. Zhao, Y. Sun and Y. Feng, 2022. Effects of gibberellins on important agronomic traits of horticultural plants. *Front. in Plant Sci.*, 13: 978223.
- Zhang, Y. J., Z.K. Xie, Y.J. Wang, L.P. An, 2011. Changes in carbohydrate metabolism and bulb growth as induced by low-temperature release of dormancy in lily bulbs. *Philippine Agric. Scientist*, 94(2): 149-154.

---

Received: March, 2025 ; Revised: May, 2025 ; Accepted: June, 2025