Scientific J. Flowers & Ornamental Plants
www.ssfop.com/journal
ISSN: 2356-7864 **doi: 10.21608/SJFOP.2023.336169**

EFFECT OF CHEMICAL FERTILIZATION AND FOLIAR SPRAYING WITH AMINO ACIDS MIXTURE ON FLOWERS QUALITY, BULBS AND BULBLETS PRODUCTIVITY OF *HIPPEASTRUM VITTATUM* PLANTS

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Scientific J. Flowers & Ornamental Plants, 10(3):217-231 (2023).

Received:
14/8/2023
Accepted:
8/9/2023

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ABSTRACT: The current research was conducted at the Ornamental Plants and Landscape Gardening Res. Dept. Nursery, Hort. Res. Inst., Agric. Res. Center, Giza, Egypt, over two consecutive seasons spanning from 2020 to 2022. The aim was to investigate the influence of NPK fertilization (0, 1.0, and 2.0 g/pot) and foliar spraying of an amino acids mixture (0, 1.0, and 3.0 ml/l), either applied individually or in combined treatments. This study focused on assessing their effects on vegetative growth, flower parameters, various chemical constituents, as well as the characteristics of bulbs and bulblets of *Hippeastrum vittatum* plants. The cultivation medium comprised a mixture of sand and clay (1:1 by volume), and the plants were grown in 20-cm pots. The results obtained indicated that various parameters were positively affected. This included an increase in height (cm), the number of leaves per plant along with their fresh and dry weights, the number of roots per plant along with their length (cm), the number of flowers per plant with their diameter (cm), and the length, as well as fresh and dry weights of flowering stalks (g). These improvements were observed when applying NPK fertilization at a rate of 2.0 g/pot, coupled with foliar spraying using an amino acids mixture at a rate of 3.0 ml/l. In this regard, the earlier treatment also led to an increase in bulb diameter (mm), along with its fresh and dry weights (g). Additionally, the characteristics of bulblets, including their number, diameter, and fresh and dry weights, showed positive effects. Moreover, the same treatment resulted in enhancements in various chemical constituents, such as chlorophylls, carotenoids in fresh leaves, total carbohydrates, and the percentages of N, P, and K in dry leaves and bulbs. Therefore, it is recommended to apply 2.0 g/pot of NPK fertilizer and foliar spray with a 3.0 ml/l amino acids mixture for the cultivation of *H. vittatum* plants in 20 cm-diameter plastic pots filled with sand + clay mixture (1:1 by volume).

Keywords: Amaryllis, *Hippeastrum vittatum*, NPK fertilization, amino acids, flowering bulbs, bulblets

INTRODUCTION

Hippeastrum or amaryllis (Fam. Amaryllidaceae) is a perennial bulbous flowering genus of about 80 species originating in Central and South America. They have large fleshy tunicated bulbs with a diameter of 5 to 12 cm. Its leaves are long-lasting evergreen. The basal leaves develop with or just after the flowers and there are 2 to 7 leaves per plant. The flowers are showy, large, and funnel-shaped with multiple colors and forms. The flower stalks emerge from winter to spring in umbels. Most known cultivars of hippeastrum are derived from 6 species including *H. vittatum*. It could be grown as houseplants or outdoors in a border or containers. *H. vittatutm* is a robust bulbous

perennial producing thick stems with umbels of 3-6 funnel-shaped, red-striped white flowers, 13 cm across in spring (Brickell, 1997 and Datta, 2022).

Supplying mineral elements by the process called fertilization is a very important factor for the floriculture sector. N, P and K are the key elements required for all plants due to their structural and functional critical roles in plants (Bhatla and Lal, 2018). Mineral fertilization greatly influenced the vegetative growth, flowering, bulbs and bulblets parameters as well as the chemical contents of a lot of ornamental bulbous crops. A lot of studies emphasized the positive impact of N.P.K fertilization on ornamental geophytes e.g. *Hippeastrum vittatum* (El-Naggar and El-Nasharty, 2009), *Hippeastrum hybridum* Hort. (Jamil *et al*., 2016), *Iris hollandica* cv. Prof. Blaauw (Alsheikhly, 2019), *Dahlia* × *hybrida* cvs. Hypnotica, Cherish Pink and Goldalia Scarlet (Henry *et al.*, 2020), *Hippeastrum* cv. Red Lion (Inkham *et al.*, 2022) and tuberose (Castañeda-Saucedo *et al.*, 2023). As proved previously by a lot of researchers, hippeastrum plants need to be fertilized regularly, as their growing season is long and they require a continuous supply of nutrients (El-Naggar and El-Nasharty, 2009).

The active plant processes leading to growth and development could be influenced by amino acids whether directly or indirectly (Aminifard and Jorkesh, 2019). Besides regulating growth, amino acids build protein, a precursor for many vital metabolites and enhance the plants' defense against different stresses (Trovato *et al*., 2021). In agricultural practices, amino acids are involved and used to enhance growth and tolerability, and a lot of studies have been carried out on this concern, especially for floriculture crops e.g. Abbass *et al.* (2020) on *Fressia hybrida*, Mustafa and Al-Saad (2020) on *Gladiolus hybrida* cvs. Far West, Comedie and Costa and Dorgham and Khedr (2021) on *Iris tingitana* cv. Golden Beauty.

This study aimed to explore the impacts of NPK fertilization and foliar spry of an amino acids mixture on the growth and quality of *Hippeastrum vittatum* plants grown in 20 cm diameter pots under open field conditions.

MATERIALS AND METHODS

During the seasons of 2020/2021 and 2021/2022, this experiment was performed at the Ornamental Plants and Landscape Gardening Res. Dept. Nursery, Hort. Res. Inst., Agric. Res. Center, Giza, Egypt to explore the impact of fertilization with NPK and amino acids both individually or in combined treatments on *Hippeastrum vittatum* (L'Her.) Herb. plants growth and quality.

Plant material:

On October 15th, healthy and uniform *H. vittatum* bulbs (3.5-4.0 cm in diameter) were procured from the Ornamental Plants Nursery at the Fac. of Agric. in Moshtohor, Benha University, Egypt, for both the first and second seasons. After careful cleaning and washing with water, each bulb was planted under open field conditions in a 20 cm diameter plastic pot filled with 2.5 kg of growing medium, consisting of a 1:1 volume ratio of clay to sand. Table (1) provides some details on the meteorological parameters at Giza Governorate during the study period, while Table (2) shows the properties of the utilized clay and sand.

Experimental layout:

The layout adopted for this experiment was a two-factor completely randomized design following the method demonstrated by Gomez and Gomez (1984). Factor A in this regard, was allocated for the three NPK fertilization rates, while factor B was assigned for the three levels of foliar spraying with amino acids mixture. This experiment contained nine treatments, each one had three replicates with nine bulbs/replicate.

Treatments:

Agri Gold Fert© product was used as a source of NPK 19:19:19 (19% N in amide, NH_4 and NO_3 forms, 19% P in $NH_4H_2PO_4$ form and 19% K in K_2SO_4 and KNO_3 forms). Three levels of NPK fertilization (0.0 without fertilization (control), 1.0 and 2.0 g/pot) were

Table 1. Some meteorological parameters at Giza Governorate during the study period (from 2020 to 2022).

Months	Temperature (°C)			Relative humidity (%)	Wind speed (m/second)	Precipitation (mm/day)	TPAR* (W/m²)
	Average	Max.	Min.				
				2020			
October	25.43	40.02	16.12	57.31	2.98	0.00	99.09
November	18.66	28.27	9.64	63.31	2.38	0.00	76.47
December	15.63	27.14	8.37	60.75	2.27	0.00	67.07
				2021			
January	14.05	27.25	4.10	58.88	2.63	0.00	72.12
February	14.16	27.72	3.72	61.69	2.37	0.94	92.09
March	15.51	32.19	4.66	62.31	2.72	3.06	113.60
April	19.87	40.48	6.09	50.06	3.19	0.13	135.83
May	27.00	41.67	14.90	36.69	3.12	0.00	149.24
June	28.16	41.45	15.86	41.38	3.47	0.00	154.32
July	30.79	43.00	20.12	41.12	2.98	0.00	149.91
August	31.07	44.01	20.37	42.88	2.84	0.00	138.30
September	27.89	40.26	17.80	51.00	3.21	0.00	122.93
October	23.92	34.99	14.47	55.12	2.98	0.05	99.48
November	20.50	33.59	11.84	61.75	2.30	0.67	76.97
December	13.43	24.20	5.10	68.50	2.63	0.34	65.35
				2022			
January	10.29	21.61	1.15	67.06	2.49	1.08	72.80
February	12.24	25.15	5.12	66.56	2.52	0.38	91.16
March	13.40	28.98	2.40	59.94	3.02	1.30	112.36
April	21.83	40.00	8.51	45.00	3.20	0.00	129.99
May	25.08	41.25	11.75	39.69	3.38	0.00	145.77
June	29.25	44.30	17.36	42.12	3.24	0.00	153.47
July	29.91	40.61	19.26	42.50	3.02	0.06	152.77
August	30.32	41.90	21.25	46.06	3.05	0.06	138.72

These parameters were edited from the data collected from NASA Power Data Access Viewer Program (https://power.larc.nasa.gov).

*** TPAR is the total photosynthetically active radiation incident on a horizontal plane at the surface of the earth under clear sky conditions.**

Table 2. The physical and chemical analyses of the used sand and clay.

Soil type	Particle size distribution (%)				S.P.	pH	E.C. (dS/m)	Cations (meq/l)				Anions (meq/l)		
	Coarse sand	Fine sand	Silt	Clay				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}
Sand	80.70	10.31	1.35	7.64	22.72	7.76	2.31	15.42	6.97	15.64	0.62	2.43	9.15	22.04
Clay	7.09	20.33	31.96	40.62	40.22	8.04	2.20	10.16	4.72	16.99	0.59	5.54	5.68	20.43

applied as a soil addition by mixing each amount with the top portion of the growing medium surface before irrigation.

Amino Suam© product was utilized to supply amino acids, both type and the amount of 15 mixture amino acids involved in this product are shown in Table (3). Furthermore, three concentrations of amino acids (0.0, 1.0, and 3.0 ml/l) were administered as a foliar spray on the leaves until runoff.

Each level of amino acids was combined with each level of fertilizers, so nine combined treatments were applied in this study. These nine treatments were applied five times, the first one was done after one month from planting (15th November) then at monthly intervals till flowering. After flowering, two additional doses of these treatments were applied on 15th May and 1st July to encourage bulbs and bulblets to develop.

Both Agri Gold Fert© and Amino Suam© are registered products by The Egyptian Ministry of Agriculture and were obtained from two agricultural companies in Egypt.

Data recorded:

Vegetative growth characteristics:

The measurement of plant height (in centimeters) was taken from the level of the soil surface to the highest point of the aerial growth, number of leaves/plant, leaves fresh and dry weights/plant (g), number of roots/plant and root length (cm).

Flowering parameters:

Number of flowers/plant, flower diameter (cm), flowering stalk length (cm), flowering stalk fresh and dry weights (g).

Bulb and bulblet characteristics:

Bulb diameter (mm), bulbs fresh and dry weights (g), number of bulblets/plant, bulblet diameter (mm), bulblets fresh and dry weights/plant (g).

Chemical composition:

Chlorophylls a, b and carotenoids (mg/g f.w.) were assessed in fresh leaves by Wellburn and Lichtenthaler (1984) method and total carbohydrates, N, P and K were determined in both dry leaves and bulbs according to Herbert *et al.* (1971), Jackson (1973), Cottenie *et al.* (1982) and Jackson (1973), respectively.

These data were collected at the end of this study (mid-August) in both seasons for the vegetative growth, bulbs and bulblets parameters and at the full opening stage of the flowers (last week of April in both seasons) for flowering parameters and pigments content (only in the second season). At the end of the second season (mid-August), total carbohydrates, N, P and K determinations were done.

Statistical analysis:

The MSTAT computer program was employed for the statistical analysis of the collected data by utilizing the analysis of variance (ANOVA) test for a two-factor completely randomized design module (Gomez and Gomez, 1984). To compare the means, Duncan's multiple range test (Duncan, 1955) was employed.

RESULTS AND DISCUSSION

1. Vegetative growth characteristics:

A significant effect was observed on vegetative growth characteristics in both seasons due to fertilizing with NPK (Table, 4). Fertilizing with NPK at 2.0 g/pot gave the highest values as recorded 37.17 and 40.24 cm for plant height, 5.64 and 5.94 for number of leaves/plant, 11.88 and 12.99 g for leaves fresh weight, 6.96 and 7.77 g for leaves dry weight, 30.11 and 30.82 for number of roots/plant and 16.71 and 17.97 cm for root length in the first and second seasons, respectively comparing to untreated plants which recorded the lowest values.

Data tabulated in Table (4) show that foliar spraying with amino acids mixture significantly increased all studied vegetative growth, the mastery effect in this regard was obtained by applying amino acids at 3.0 ml/l as gave 30.82 and 34.73 cm for plant height, 5.03 and 5.31 for number of leaves/plant,

Table 3. Amino acids involved in Amino Suam© product.

Amino acid	Amount (g/100 ml)	Amino acid	Amount (g/100 ml)
Glutamic acid	2.24	**Threonine**	1.02
Proline	1.98	**Leucine**	0.68
Serine	1.77	**Phenylalanine**	0.66
Glycine	1.64	**Isoleucine**	0.61
Aspartic acid	1.44	**Lysine**	0.49
Arginine	1.40	**Tyrosine**	0.21
Valine	1.32	**Histidine**	0.18
Alanine	1.04		

Table 4. Effect of NPK fertilization, amino acids mixture and their interaction on some vegetative growth and roots characteristics of *Hippeastrum vittatum* during 2020/2021 and 2021/2022 seasons.

Treatments		Plant height (cm)		Number of leaves/plant		Leaves f.w. (g)		Leaves d.w. (g)		Number of roots/plant		Root length (cm)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Effect of NPK fertilization (g/pot)													
0.0		20.19 c	22.23 c	3.36 c	3.53 c	8.62 c	9.48 c	4.42 c	5.16 c	17.67 c	18.06 c	11.06 c	12.39 c
1.0		25.85 b	30.56 b	4.28 b	4.64 b	9.83 b	11.24 b	5.49 b	6.41 b	21.42 b	22.36 b	12.55 b	14.51 b
2.0		37.17 a	40.24 a	5.64 a	5.94 a	11.88 a	12.99 a	6.96 a	7.77 a	30.11 a	30.82 a	16.71 a	17.97 a
Effect of amino acids mixture (ml/l)													
0.0		24.42 c	27.20 c	3.87 c	4.02 c	9.58 c	10.61 c	5.18 c	5.90 c	20.02 c	20.34 c	12.23 c	13.58 c
1.0		27.96 b	31.10 b	4.38 b	4.79 b	10.03 b	11.15 b	5.63 b	6.18 b	22.96 b	24.11 b	13.01 b	14.46 b
3.0		30.82 a	34.73 a	5.03 a	5.31 a	10.72 a	11.95 a	6.06 a	7.25 a	26.22 a	26.78 a	15.08 a	16.82 a
Effect of NPK × Amino acids (AA)													
NPK	**AA**												
0.0	**0.0**	17.88 i	16.17 g	2.73 g	2.53 g	8.24 h	8.69 f	4.12 h	4.64 g	14.40 g	13.90 f	10.34 g	10.99 g
	1.0	20.58 h	25.07 f	3.40 f	4.00 f	8.58 gh	9.71 e	4.52 g	4.76 g	18.33 f	19.13 e	11.15 f	12.79 f
	3.0	22.11 g	25.44 f	3.93 e	4.07 f	9.03 fg	10.06 e	4.63 g	6.08 f	20.27 ef	21.13 d	11.70 ef	13.38 ef
1.0	**0.0**	23.52 f	27.61 e	4.13 de	4.33 ef	9.44 ef	10.93 d	5.12 f	6.16 f	20.47 d-f	22.20 d	12.27 de	13.73 de
	1.0	25.16 e	28.84 e	4.27 de	4.60 de	9.70 e	11.04 d	5.52 e	6.37 e	21.33 de	22.53 d	12.51 d	14.05 d
	3.0	28.86 d	35.24 d	4.43 cd	5.00 cd	10.36 d	11.75 c	5.83 d	6.70 d	22.47 d	22.33 d	12.88 d	15.74 c
2.0	**0.0**	31.85 c	37.83 c	4.73 c	5.20 c	11.06 c	12.21 c	6.31 c	6.92 c	25.20 c	24.93 c	14.08 c	16.02 bc
	1.0	38.15 b	39.38 b	5.47 b	5.77 b	11.80 b	12.72 b	6.85 b	7.40 b	29.20 b	30.67 b	15.37 b	16.55 b
	3.0	41.50 a	43.52 a	6.73 a	6.87 a	12.76 a	14.05 a	7.73 a	8.98 a	35.93 a	36.87 a	20.67 a	21.34 a

Values with the same letters within columns for both NPK fertilization, amino acids foliar spraying and their interaction are not significant according to Duncan's multiple range test.

10.72 and 11.95 g for leaves fresh weight, 6.06 and 7.25 g for leaves dry weight, 26.22 and 26.78 for number of roots/plant and 15.08 and 16.82 cm for root length in both seasons, respectively comparing to unsprayed plants.

Table (4) shows the effect of the combination of fertilization and foliar spraying with amino acids mixture on the vegetative growth of hippeastrum, it was evident that NPK at 2.0 g/pot + amino acids at 3.0 ml/l outperformed the other treatments as produced the highest values in terms of plant height, number of leaves/plant, leaves fresh weight, leaves dry weight, number of roots/plant and root length (41.50 and 43.52 cm, 6.73 and 6.87, 12.76 and 14.05 g, 7.73 and 8.98 g, 35.93 and 36.87 and 20.67 and 21.34 cm in both seasons, respectively).

2. Flowering characteristics:

Flowering characteristics of hippeastrum also positively responded to NPK fertilization (Table, 5). NPK at 2.0 g/pot produced the highest values of number of flowers/plant (2.22 and 2.49), flower diameter (12.04 and 12.00 cm), flower stalk length (29.78 and 32.86 cm), flower stalk fresh weight (44.70 and 53.05 g) and flower stalk dry weight (18.55 and 19.91 g) for both seasons, respectively in comparison to other treatments.

Amino acids mixture positively influenced hippeastrum flowering characteristics (Table, 5). The treatment of amino acids at 3.0 ml/l produced the elevated values of number of flowers, flower diameter, flower stalk length, flower stalk fresh and dry weights, with 1.87 and 1.93, 10.54 and 10.42 cm, 27.16 and 29.26 cm, 41.26 and 48.22 g, and 16.43 and 18.67 g, respectively, for both seasons.

About the interaction between NPK fertilization and amino acids mixture, NPK fertilization at 2.0 g/pot produced the highest values of flowering parameters when combined with the highest rate of amino acids (3.0 ml/l) compared to control and other treatments. This superior combined treatment resulted in 2.53 and 2.80 for number of flowers/plant, 13.47 and 13.27 cm for flower diameter, 33.51 and 33.80 cm for flower stalk length, 50.93 and 64.71 g for flower stalk fresh weight and 19.33 and 22.17 g for flower stalk dry weight in both seasons, respectively (Table, 5).

3. Bulb characteristics:

The application of NPK at 2.0 g/pot increased the diameter (54.44 and 54.53 mm) and fresh (81.17 and 81.82 g) and dry (13.26 and 13.93 g) weights of the bulbs to the highest values for the first and second seasons respectively, in comparison to the untreated control (Table, 6).

Data presented in Table (6) cleared that foliar application of amino acids mixture significantly enhanced the bulb characteristics compared to the non-treated

Table 5. Effect of NPK fertilization, amino acids mixture and their interaction on some flowering characteristics of *Hippeastrum vittatum* during 2020/2021 and 2021/2022 seasons.

Treatments		Number of flowers/plant		Flower diameter (cm)		Flowering stalk length (cm)		Flowering stalk f.w. (g)		Flowering stalk d.w. (g)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Effect of NPK fertilization (g/pot)											
0.0		1.13 c	1.13 c	8.22 c	8.32 c	21.05 c	21.18 c	28.39 c	31.92 c	11.61 c	13.38 c
1.0		1.60 b	1.62 b	9.17 b	9.08 b	24.65 b	29.14 b	37.06 b	40.84 b	15.03 b	17.59 b
2.0		2.22 a	2.49 a	12.04 a	12.00 a	29.78 a	32.86 a	44.70 a	53.05 a	18.55 a	19.91 a
Effect of amino acids mixture (ml/l)											
0.0		1.49 b	1.60 b	9.04 c	9.08 c	23.26 c	25.48 c	33.25 c	37.18 c	13.71 c	15.15 c
1.0		1.60 b	1.71 b	9.84 b	9.90 b	25.07 b	28.43 b	35.65 b	40.41 b	15.05 b	17.06 b
3.0		1.87 a	1.93 a	10.54 a	10.42 a	27.16 a	29.26 a	41.26 a	48.22 a	16.43 a	18.67 a
Effect of NPK × Amino acids (AA)											
NPK	**AA**										
0.0	**0.0**	1.00 f	1.20 ef	8.02 g	8.08 f	19.28 h	19.73 f	24.47 g	27.73 h	9.44 g	10.35 g
	1.0	1.07 f	1.00 f	8.18 fg	8.32 f	21.42 g	21.52 e	26.88 f	29.88 g	11.94 f	14.17 f
	3.0	1.33 e	1.20 ef	8.47 e-g	8.55 ef	22.47 fg	22.29 e	33.82 e	38.14 f	13.43 e	15.61 e
1.0	**0.0**	1.47 de	1.40 de	8.77 ef	8.75 d-f	23.80 ef	24.56 d	35.26 de	39.67 e	13.90 de	16.60 d
	1.0	1.60 cd	1.67 cd	9.03 e	9.07 de	24.66 de	31.15 c	36.90 d	41.03 de	14.67 d	17.95 c
	3.0	1.73 c	1.80 c	9.70 d	9.43 d	25.49 cd	31.70 bc	39.03 c	41.81 d	16.51 c	18.24 bc
2.0	**0.0**	2.00 b	2.20 b	10.35 c	10.42 c	26.69 c	32.16 b	40.00 c	44.14 c	17.79 b	18.50 bc
	1.0	2.13 b	2.47 b	12.32 b	12.32 b	29.13 b	32.62 b	43.16 b	50.31 b	18.53 b	19.06 b
	3.0	2.53 a	2.80 a	13.47 a	13.27 a	33.51 a	33.80 a	50.93 a	64.71 a	19.33 a	22.17 a

Values with the same letters within columns for both NPK fertilization, amino acids foliar spraying and their interaction are not significant according to Duncan's multiple range test.

Table 6. Effect of NPK fertilization, amino acids mixture and their interaction on some bulb characteristics of *Hippeastrum vittatum* during 2020/2021 and 2021/2022 seasons.

Treatments		Bulb diameter (mm)		Bulb f.w. (g)		Bulb d.w. (g)	
		1st	2nd	1st	2nd	1st	2nd
Effect of NPK fertilization (g/pot)							
0.0		38.52 c	38.70 c	35.74 c	36.30 c	6.44 c	6.91 c
1.0		45.19 b	45.61 b	55.84 b	56.42 b	8.62 b	10.73 b
2.0		54.44 a	54.53 a	81.17 a	81.82 a	13.26 a	13.93 a
Effect of amino acids mixture (ml/l)							
0.0		42.42 c	42.84 c	50.11 c	50.31 c	8.19 c	9.16 c
1.0		45.66 b	45.73 b	55.64 b	56.13 b	9.44 b	10.73 b
3.0		50.07 a	50.27 a	67.00 a	68.09 a	10.69 a	11.68 a
Effect of NPK × Amino acids (AA)							
NPK	**AA**						
0.0	**0.0**	35.47 i	35.90 i	30.67 i	31.27 i	5.01 g	5.24 g
	1.0	39.13 h	38.67 h	33.72 h	33.42 h	6.65 f	7.42 f
	3.0	40.97 g	41.53 g	42.83 g	44.20 g	7.64 ef	8.06 f
1.0	**0.0**	41.73 f	42.70 f	49.39 f	49.89 f	7.93 e	9.52 e
	1.0	44.67 e	45.03 e	53.29 e	53.76 e	8.62 de	11.03 d
	3.0	49.17 d	49.10 d	64.84 d	65.61 d	9.31 d	11.64 d
2.0	**0.0**	50.05 c	49.92 c	70.28 c	69.78 c	11.61 c	12.71 c
	1.0	53.19 b	53.49 b	79.90 b	81.20 b	13.05 b	13.74 b
	3.0	60.08 a	60.18 a	93.33 a	94.47 a	15.12 a	15.35 a

Values with the same letters within columns for both NPK fertilization, amino acids foliar spraying and their interaction are not significant according to Duncan's multiple range test.

plants as recorded 50.07 and 50.27 mm for bulb diameter, 67.00 and 68.09 g for bulb fresh weight and 10.69 and 11.68 g for bulb dry weight in both seasons, respectively.

As for the effect of the combined treatments between NPK fertilization and amino acids mixture, the recorded data proved a significant influence of NPK at 2.0 g/pot + amino acids at 3.0 ml/l on the bulb characteristics compared to the non-treated control. The registered results were 60.08 and 60.18 mm for bulb diameter, 93.33 and 94.47 g for bulb fresh weight and 15.12 and 15.35 g for bulb dry weight in both seasons, respectively (Table, 6).

4. Bulblet characteristics:

The trend observed in the case of vegetative growth and bulbs was also observed in the case of bulblet characteristics, concerning NPK fertilization (Table, 7). The superior effect was resulted by NPK at 2.0 g/pot as recorded 9.69 and 9.71 for number of bulblets/plant, 22.25 and 22.28 mm for bulblet diameter, 76.65 and 90.26 g for bulblets fresh weight/plant and 16.86 19.45 g for bulblets dry weight/plant for both seasons, respectively.

Foliar spraying with amino acids mixture at 3.0 ml/l conducted the highest values compared to the control (Table, 7). The obtained values were 7.64 and 7.62 for number of bulblets/plant, 18.89 and 18.87 mm for bulblet diameter, 56.03 and 66.00 g for bulblets fresh weight/plant and 12.02 and 13.86 g for bulblets dry weight/plant for both seasons, respectively.

Compared to the control and other treatments, it was clear that NPK at 2.0 g/pot + amino acids at 3.0 ml/l recorded the elevated values for all bulblet characteristics (Table, 7). The results were 9.80 and 9.67 for number of bulblets/plant, 24.30 and 24.32 mm for bulblet diameter, 84.53 and 93.93 g for bulblets fresh weight/plant, and 19.00 and 21.11 g for bulblets dry weight/plant for both seasons, respectively.

Table 7. Effect of NPK fertilization, amino acids mixture and their interaction on some bulblet characteristics of *Hippeastrum vittatum* during 2020/2021 and 2021/2022 seasons.

Treatments		Number of bulblets/plant		Bulblet diameter (mm)		Bulblets f.w./plant (g)		Bulblets d.w./plant (g)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Effect of NPK fertilization (g/pot)									
0.0		4.71 c	4.73 c	13.08 c	12.81 c	25.78 c	32.21 c	4.83 c	6.00 c
1.0		6.71 b	6.82 b	16.34 b	16.49 b	42.18 b	53.95 b	8.71 b	10.67 b
2.0		9.69 a	9.71 a	22.25 a	22.28 a	76.65 a	90.26 a	16.86 a	19.45 a
Effect of amino acids mixture (ml/l)									
0.0		6.04 b	6.07 b	15.87 c	15.79 c	38.51 c	47.61 b	7.91 c	9.51 c
1.0		7.42 a	7.58 a	16.91 b	16.91 b	50.07 b	62.81 a	10.46 b	12.74 b
3.0		7.64 a	7.62 a	18.89 a	18.87 a	56.03 a	66.00 a	12.02 a	13.86 a
Effect of NPK × Amino acids (AA)									
NPK	**AA**								
0.0	**0.0**	3.80 e	3.67 f	12.38 h	11.73 g	20.16 f	23.29 f	3.65 f	4.25 f
	1.0	5.00 d	5.20 e	13.13 gh	12.97 f	27.52 ef	35.67 e	5.09 ef	6.58 e
	3.0	5.33 d	5.33 e	13.73 fg	13.72 ef	29.67 e	37.67 e	5.74 ef	7.16 e
1.0	**0.0**	5.67 cd	5.80 e	14.60 f	14.65 e	32.11 de	42.43 e	6.41 de	8.27 e
	1.0	6.67 c	6.80 d	15.78 e	16.25 d	40.54 d	53.01 d	8.40 d	10.41 d
	3.0	7.80 b	7.87 c	18.65 d	18.57 c	53.90 c	66.40 c	11.33 c	13.31 c
2.0	**0.0**	8.67 b	8.73 bc	20.63 c	21.00 b	63.27 b	77.10 b	13.66 b	16.02 b
	1.0	10.60 a	10.73 a	21.82 b	21.52 b	82.15 a	99.75 a	17.91 a	21.22 a
	3.0	9.80 a	9.67 b	24.30 a	24.32 a	84.53 a	93.93 a	19.00 a	21.11 a

Values with the same letters within columns for both NPK fertilization, amino acids foliar spraying and their interaction are not significant according to Duncan's multiple range test.

5. Pigments contents in fresh leaves:

Chlorophyll a and carotenoids content reached the highest significant values (0.36 and 0.21 mg/g f.w., respectively), when compared with the other treatments (Fig., 1), as a result of fertilizing with the highest fertilization rate (NPK at 2.0 g/pot). While NPK fertilization at 1.0 g/pot increased chlorophyll b to the highest value (0.14 mg/g f.w.).

As shown in Fig. (2) the same trend was obtained regarding the effect of amino acids mixture, whereas the highest rates of amino acids (3.0 ml/l) produced the highest contents of both chlorophyll a and carotenoids (0.31 and 0.19 mg/g f.w., respectively). On the other hand, the highest value of chlorophyll b was obtained by non-treated plants (control) as recorded 0.12 mg/g f.w.

The combined treatment composed of NPK at 2.0 g/pot + amino acids at 3.0 ml/l significantly resulted in the highest values of chlorophyll a (0.43 mg/g f.w.) and carotenoids (0.24 mg/g f.w.) in comparison to control and other treatments (Table, 8). Also, it can be noticed that NPK at 1.0 g/pot + amino acids at both 0.0 and 1.0 ml/l gave the highest significant values for chlorophyll b (0.24 and 0.26 mg/g f.w.) compared to control and other treatments.

6. Chemical composition of:

a. Dry leaves:

Data reported in Fig. (1) show that NPK at 2.0 g/pot significantly enhanced total carbohydrates, N %, P % and K % with the highest values of 24.19, 2.86, 0.65 and 2.33%, respectively compared to control. NPK at 1.0 g/pot participated in the previous treatment without significant difference between them in the case of K % as recorded 2.25%.

The highest significant values of total carbohydrates, N %, P % and K % were obtained by amino acids at 3.0 ml/l which resulted in 22.22, 2.41, 0.57 and 2.26%, respectively compared to control. Amino

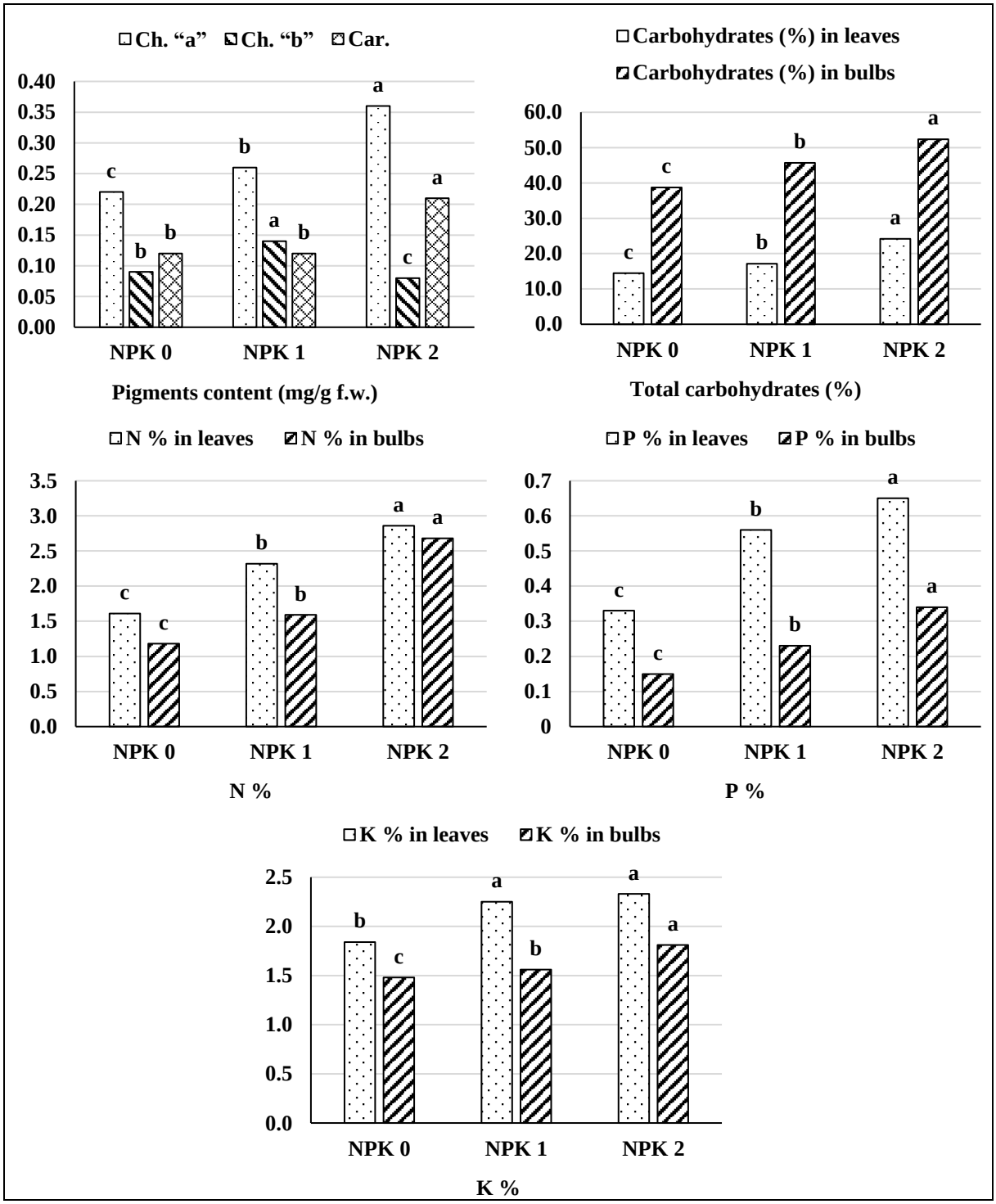

Fig. 1. Effect of NPK fertilization on some chemical constituents of *Hippeastrum vittatum* leaves and bulbs at the end of 2021/2022 season. NPK 0, NPK 1 and NPK 2 are chemical fertilization with NPK at 0.0, 1.0 and 2.0 g/pot, respectively.

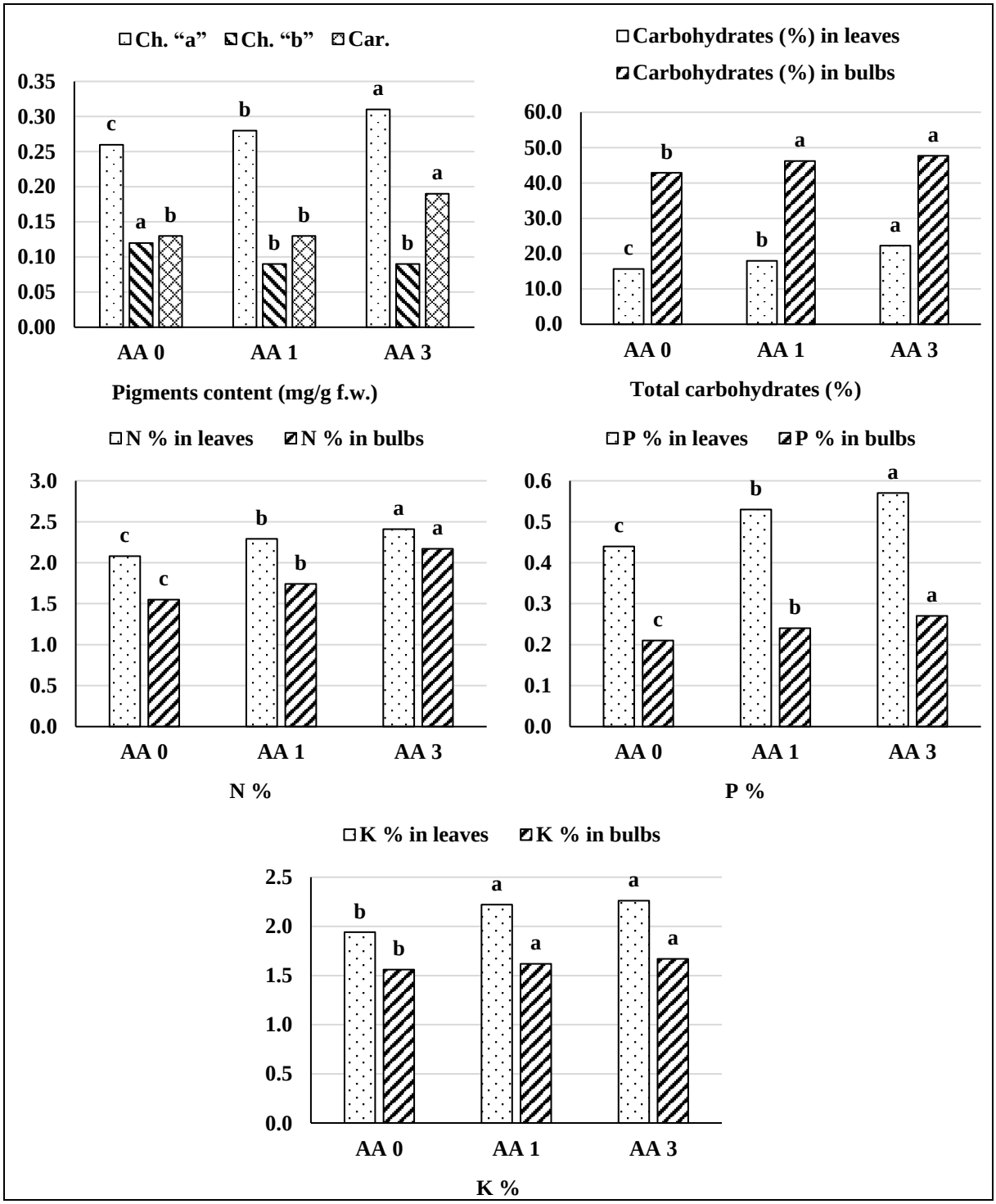

Fig. 2. Effect of amino acids mixture on some chemical constituents of *Hippeastrum vittatum* leaves and bulbs at the end of 2021/2022 season. AA 0, AA 1 and AA 3 are foliar spraying with amino acids mixture at 0.0, 1.0 and 3.0 ml/l, respectively.

Table 8. Effect of interaction between NPK fertilization and amino acids mixture (AA) on some chemical constituents of *Hippeastrum vittatum* leaves and bulbs at the end of 2021/2022 season.

Treatments		Pigments content in the leaves (mg/g f.w.)			Total Carbohydrates (%)		N %		P %		K %	
NPK (g/pot)	AA (ml/l)	Ch. "a"	Ch. "b"	Car.	Leaves	Bulbs	Leaves	Bulbs	Leaves	Bulbs	Leaves	Bulbs
0.0	**0.0**	0.21 f	0.12 b	0.09 d	12.69 e	37.10 f	1.32 f	0.97 g	0.21 h	0.11 g	1.33 e	1.46 c
	1.0	0.22 f	0.08 de	0.11 d	15.22 d	39.14 ef	1.71 e	1.20 f	0.37 g	0.18 f	2.04 d	1.48 c
	3.0	0.24 e	0.07 e	0.16 c	15.54 d	39.86 ef	1.80 e	1.38 e	0.42 f	0.18 f	2.14 cd	1.49 c
1.0	**0.0**	0.24 e	0.16 a	0.10 d	16.19 d	41.40 e	2.21 d	1.46 e	0.48 e	0.21 e	2.18 b-d	1.52 c
	1.0	0.26 d	0.15 a	0.10 d	17.47 c	46.39 d	2.28 d	1.62 d	0.59 d	0.21 e	2.29 a-c	1.52 c
	3.0	0.26 d	0.12 b	0.17 c	17.84 c	49.16 cd	2.48 c	1.69 d	0.61 c	0.27 d	2.29 a-c	1.64 b
2.0	**0.0**	0.31 c	0.09 cd	0.19 b	18.16 c	49.99 bc	2.72 b	2.23 c	0.61 bc	0.31 c	2.31 ab	1.69 b
	1.0	0.35 b	0.04 f	0.19 b	21.11 b	53.08 ab	2.89 a	2.39 b	0.63 b	0.33 b	2.32 ab	1.87 a
	3.0	0.43 a	0.09 c	0.24 a	33.29 a	54.09 a	2.96 a	3.43 a	0.69 a	0.37 a	2.37 a	1.89 a

Values with the same letters within columns for both NPK fertilization, amino acids foliar spraying and their interaction are not significant according to Duncan's multiple range test.

acids at 1.0 ml/l participated in the previous treatment without significant difference between them in the case of K % as recorded 2.22% (Fig., 2).

A significant interaction between NPK fertilization and amino acids foliar spraying was observed in the chemical composition of dry leaves (Table, 8). The combined treatment of NPK at 2.0 g/pot + amino acids at 3.0 ml/l significantly produced the highest values in the case of total carbohydrates (33.29%) and P % (0.69%). This previous treatment shared the combined treatment of NPK at 2.0 g/pot + amino acids at 1.0 ml/l in its effect in the case of N % as resulted in 2.96 and 2.89%, respectively. Although NPK at 2.0 g/pot + amino acids at 3.0 ml/l gave the highest value in the case of K % (2.37), no significant differences were observed between all combined treatments composed of NPK at 1.0 or 2.0 g/l + all amino acids rates, the only exception was observed by NPK at 1.0 + amino acids at 0.0 ml/l which resulted in less value.

b. Dry bulbs:

It is clear in Fig. (1) that the NPK fertilization at 2.0 g/pot significantly produced the highest values (52.39% for total carbohydrates, 2.68% for N, 0.34% for P and 1.81% for K) in comparison with untreated control plants.

Amino acids at 3.0 ml/l gave the superior significant values of total carbohydrates, N %, P % and K % with results of 47.70, 2.17, 0.27 and 1.67%, respectively compared to control. Treatment of amino acids at 1.0 ml/l shared 3.0 ml/l, without significant differences, in the case of total carbohydrates (46.20%) and K % (1.62%) in bulbs (Fig., 2).

In most cases, the combined treatment of NPK at 2.0 g/pot + amino acids at 3.0 ml/l significantly recorded the superior values for total carbohydrates (54.09%), N % (3.43%), P % (0.37%) and K % (1.89%) compared to control (Table, 8). It can be also observed that no significant differences were detected between the previously mentioned combined treatment and the combined treatment of NPK at 2.0 g/pot + amino acids at 3.0 ml/l in the case of total carbohydrates (53.08%) and K % (1.87%).

The results regarding the positive effect of fertilizing with NPK were previously reported in a lot of studies. El-Naggar and El-Nasharty (2009) determined that elevating chemical fertilization levels led to the highest values across various parameters, including the number of leaves, leaf length, fresh and dry weights of leaves, number of flowering stalks per plant, flower stalk length, flower diameter, bulb diameter, fresh and dry weights of bulbs, number of bulblets per

plant, bulblets' dry weight, total chlorophyll, and the content of N, P, and K in the leaves of *Hippeastrum vittatum*. Jamil *et al.* (2016) on *Hippeastrum hybridum* Hort. observed a great influence of NPK fertilization by recording high values in the case of leaves number/plant, number of flowers/plant, flower length and diameter. Also, Nagappa *et al.* (2016) showed that the application of 250:250:250 kg NPK/ha on tuberose (*Polianthes tuberosa*) cv. Shringar resulted in superior-quality flowers. Similarly, the highest values for plant height, number of leaves and flowers per plant, number of bulblets per plant, and bulblet weight were observed in *Lilium longiflorum* sp. Zephyranthes were obtained by 150:100:80 kg NPK/ha (Lokeshwar Prasad *et al*., 2017), the tallest plants and No. of leaves/plant, tallest flower scape, maximum diameter of flower bud and flowers of *Amaryllis belladonna* were obtained by the application of N125 :P50 :K125 kg/ha (Sharma *et al*., 2017). Durga *et al*. (2018) on *Gladiolus hybridus* Hort. cv. Trader Horn found that 300 kg N, 120 kg P and 120 kg K/ha demonstrated to be highly effective, they enhanced height, leaves number, length of flowering spike, and florets number per spike and spike yield. Alsheikhly (2019) on *Iris hollandica* cv. Prof. Blaauw, reported that stem diameter, fresh weight of flowering stem and bulblets were increased by NPK fertilization. Inkham *et al*. (2022) on hippeastrum cv. Red Lion showed that 2.5 or 5 g/pot of 15N-15P_2O_5-15K_2O promoted plant height, number of leaves per plant, bulb circumference and new bulbs number. Castañeda-Saucedo *et al.* (2023) on *Agave amica* reported that the fertilization formula of 300:200:200 NPK produced the highest values of spike length and the number of spikes and flowers as well as corms/plant.

This study showed a great influence of fertilization with NPK on hippeastrum plants. N, P and K are the key elements required by the plants due to their structural and functional critical roles. Nitrogen plays a crucial role in the composition of various biological compounds such as nitrogenous bases, amino acids, cofactors, alkaloids, coenzymes, chlorophyll, and even some hormones like IAA. Phosphorus is essential in the form of phosphate for sugar, as an ester in DNA and RNA, and in the structure of phospholipids found in cell membranes. Additionally, it is a key component of ATP. Potassium serves as an enzyme activator, plays a vital role in protein synthesis, and is involved in the production of sugars and starches. (Bhatla and Lal, 2018).

As for the effect of amino acids, there was an agreement with the present results by El-Naggar and Swedan (2009) on *Hippeastrum vittatum*, Herb., Abbass *et al*. (2020) on *Fressia hybrida*, Mustafa and Al-Saad (2020) on *Gladiolus hybrida* cvs. Far West, Comedie and Costa and Dorgham and Khedr (2021) on *Iris tingitana* cv. Golden Beauty. On the same side, Al-Fatlawi *et al.* (2022) reported that amino acids at 150 mg/l enhanced the number of leaves, plant height, leaf area, and content of chlorophyll, N, P, and K, flower stalk length, and number and diameter of flowers.

To explain such beneficial roles of amino acids it is worthy to mention that amino acids serve as the fundamental components of proteins and contribute to glutamine biosynthesis, a precursor of nucleotides, hormones and nitrogen compounds with low molecular-weight (Lonnerdal, 2000 and Alcázar, *et al.*, 2010). On the flip side, the translocation of amino acids is crucial in plants. Unlike reduced carbon, which is exclusively translocated by the phloem, amino acids undergo translocation in both the phloem and xylem. Consequently, the retranslocation of amino acids facilitates nitrogen recycling between roots and shoots and expedites the translocation of immobile nutrient elements, such as zinc, within the plant (Ortiz-Lopez *et al*., 2000). As reported by researchers, amino acids and their combinations increase the bulb yield and quality of garlic by stimulating the synthesis of protein, amino acids, enzymes, photosynthetic pigments, and several vitamins, activating phytohormones, and accelerating the cell cycle (Turfan and Turan,

2023). Researchers also reported that directly being involved in nitrogen assimilation thanks to their ammonium (NH_4^+) contents, amino acids and their derivatives stimulated the synthesis of chlorophyll, protein, and phytohormones, as well as stimulating the cell division (Hildebrandt *et al*., 2015 and Aghaye Noroozlo *et al*., 2019). Similarly, Majkowska-Gadomska *et al.* (2019) determined that exogenous amino acid treatments increased the nitrate content of winter garlic varieties' cloves. On the other hand, glutamic acid (contained in the amino acids mixture used in the present study) is an important ammonium recipient, it transforms into other amino acids such as proline, glycine, and arginine, and plays important roles in chlorophyll synthesis, activation of vegetal hormones, cell division, and phytochelatin activities (Sun *et al*., 2019).

Therefore, it is recommended to apply 2.0 g/pot of NPK fertilizer and foliar spray with a 3.0 ml/l amino acids mixture for the cultivation of *Hippeastrum vittatum* plants in 20 cm-diameter plastic pots filled with a sand + clay mixture (1:1 by volume). This regimen is suggested to achieve optimal growth, flowering, as well as maximize productivity in terms of bulbs and bulblets.

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تأثير التسميد الكيماوي والرش بمخلوط الأحماض الأمينية على جودة أزهار و إنتاجية أبصال وبصيلات نبات الهيبسترم

بشره عبدالله السيد محمد، وردة عبد السميع علي علي، طارق محمد نور الدين أحمد
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تم إجراء هذه الدراسة بمشتل قسم بحوث الزينة وتنسيق الحدائق، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر خلال موسمين إمتدا من ٢٠٢٠ حتى ٢٠٢٢ بهدف دراسة تأثير كلاً من التسميد الكيماوي (نيتروجين، فوسفور، بوتاسيوم) بتركيزات صفر، ١,٠ و ٢,٠ جم/إصيص والرش الورقي بمخلوط الأحماض الأمينية بتركيزات (٠و ١,٠ و ٣,٠ مل/لتر) منفردين أو بالتداخل فيما بينهما على النمو الخضري، مواصفات الأزهار، بعض المكونات الكيميائية علاوة على خصائص الأبصال والبصيلات لنبات الهيبسترم. تم زراعة النباتات في أصص بلاستيكية ذات قطر ٢٠ سم وتحتوي على ٢,٥ كجم من بيئة زراعة تكونت من طمي + رمل بمعدل ١:١ حجماً. أشارت النتائج التي تم الحصول عليها إلى تأثير إيجابي للمواد المستعملة على الصفات تحت الدراسة متضمناً ذلك زيادة في الإرتفاع، عدد الأوراق لكل نبات وكذلك أوزانها الطازجة والجافة، عدد الجذور لكل نبات مع طولها، عدد الأزهار لكل نبات وأقطارها وكذلك الطول والوزن الطازج والجاف للسيقان الزهرية. هذا التحسن تم ملاحظته للنباتات التي تم معاملتها بالتسميد الكيماوي بمعدل ٢,٠ جم/إصيص + الرش الورقي بمخلوط الأحماض الأمينية بمعدل ٣,٠ مل/لتر. كذلك أدت هذه المعاملة إلى زيادة قطر البصلة ووزنها الطازج والجاف. بالإضافة إلى ذلك فإن خصائص البصيلات متضمنة عددها، قطرها، أوزانها الطازجة والجافة تأثرت إيجابياً بهذه المعاملة التي حسنت أيضاً المحتوى الكيماوي للنبات مثل الكلوروفيلات، الكاروتينويدات، والنسب المئوية للكربوهيدرات الكلية والنيتروجين والفوسفور والبوتاسيوم. بناء على ذلك فإنه يوصى بتسميد نباتات الهيبسترم المزروعة في أصص ذات قطر ٢٠ سم مملوءة بالطمي والرمل بنسبة ١:١ حجماً بالسماد الكيماوي (NPK) بمعدل ٢,٠ جم/إصيص بالإضافة إلى الرش الورقي بمخلوط الأحماض الأمينية بمعدل ٣,٠ مل/لتر.