Journal of Applied Horticulture, 26(2): 175-181, 2024
https://doi.org/10.37855/jah.2024.v26i02.33
Journal of Applied Horticulture
ISSN: 0972-1045

Enhancing *Iris tingitana* cv. Wedgewood productivity with chemical, bio-fertilizers and irrigation

Taghreed E. Eissa[1]*, Hassan A. Elfeky[1], Alaa El deen Shaheen[2], Feng Xu [3,4]* and Mohamed A.A. Ahmed[5]*

[1]Ornamental Plants and Landscape Gardening Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt. [2]Sandy and Limestone Lands Department, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt. [3]Key Labouratory for Flower Breeding of Yunnan Province, National Engineering Research Center for Ornamental Horticulture, Floriculture Research Institute, Yunnan Academy of Agricultural Sciences, Kunming, China. [4]Yunnan Seed Labouratory, Kunming 650200, China. [5]Plant Production Department (Horticulture-Medicinal and Aromatic Plants), Faculty of Agriculture (Saba Basha), Alexandria University, Alexandria 21531, Egypt.
**E-mail: dr.taghreed.eissa.2019@gmail.com; 148422486@qq.com; drmohamedmarey19@alexu.edu.eg*

Abstract

This study aimed to investigate the impact of various fertilization methods and doses on the growth, flowering, and chemical composition of *Iris tingitana* cv. Wedgewood plants. The research aimed to address challenges hindering Iris plant development and bulb production, ultimately striving to cultivate high-quality plants suitable for Egyptian conditions. Conducted over two seasons (2021-2022 and 2022-2023) at the Horticulture Research Institute's nursery of the Agriculture Research Center in Giza, Egypt, the experiment followed a factorial design with a randomized complete design (RCD) and three replicates. Results revealed that plants treated with 5 g/pot of phosphorein and 2 g/pot of kristalon, with irrigation intervals every 10 days after sowing (DAS), exhibited superior growth parameters. These included increased vegetative growth in terms of height, stem length, number of leaves per plant, fresh weight of cut spikes, diameter of the spike stem, and earliest flowering compared to other treatments across both seasons. Conversely, the application of 2 g/pot of kristalon and nitrobine, combined with irrigation intervals every 10 DAS, ranked second in enhancing plant growth and flowering characteristics in both seasons.

Key words: *Iris tingitana* cv. Wedgwood; kristalon; nitrobine; phosphorein; irrigation intervals (DAS)

Introduction

Iris, a perennial bulbous or rhizomatous plant, belongs to the Iridaceae family and comprises about 200 species native to cooler regions. Renowned for their brilliant and magnificent flowers, irises have become popular ornamental plants in gardens and parks. The unique mauve coloring of Iris flowers has significantly boosted their demand in both domestic and international markets, establishing a substantial economic value. Irises are widely used for various decorative purposes, including cut flower production, rock gardens, water gardens, and alpine homes, and they also possess medicinal properties (Wilson, 2011; Atwa *et al.*, 2023).

The Iris tingitana cultivar Wedgewood is particularly valued for its aesthetic appeal and export potential. However, under Egyptian conditions, there has been an annual decline in bulb yield, necessitating imports from the Netherlands. To address this issue, it is crucial to explore factors that can enhance local production of high-yielding, quality bulbs.

Insufficient fertilization is a major challenge in iris cultivation, leading to hindered growth and increased plant mortality. Although chemical fertilizers such as nitrogen (N), phosphorus (P), and potassium (K) improved plant output in the 1970s, their unbalanced use has resulted in soil health problems, nutrient deficiencies, loss of microbial activity, and reduced fertility, ultimately affecting crop yields (Singh *et al.*, 2017; Abdel-Said *et al.*, 2018).

Biofertilizers, including phosphate-solubilizing bacteria and azola, are increasingly used in sustainable agriculture due to their low cost and positive impact on plant health and productivity. Phosphate-solubilizing microorganisms (PSM) like bacteria enhance soil biological integrity, reduce environmental contamination, aid plant water absorption, improve nutrient cycles, and enhance photosynthetic mechanisms. Phosphorein and nitrobine are two widely used biofertilizers, with nitrobine containing non-symbiotic nitrogen-fixing bacteria and phosphorein containing *Bacillus megatherium* bacteria. These bacteria provide beneficial phosphorus for plant growth, boosting iris production and quality. Several studies have shown the positive effects of biofertilizers on Iris output, supporting the conclusion that biofertilizers enhance iris production and quality (Abdel-Wahab, 2013; Mohamed and Ghatas, 2016; Gomaa *et al.*, 2018; Ghatas and Mohamed, 2020; Sarmah and Sarma, 2023).

Irrigation is equally crucial for plant growth, aiding in germination, nutrient uptake and transport, and facilitating biological processes. It helps maintain plant turgidity and supports photosynthesis, which sustains plant life. The timing and frequency of irrigation vary depending on the type and needs of the plants (Bostan *et al.*, 2014).

This research aims to investigate the effects of chemical and bio-fertilizer combinations and optimized irrigation intervals on the productivity of *I. tingitana* cv. Wedgewood plants. By integrating these approaches, we aim to enhance the yield and quality of locally produced iris bulbs, reducing the need for imports and supporting sustainable agricultural practices.

Materials and methods

This outdoor experimental research was conducted at the nursery of the Horticulture Research Institute, Agriculture Research Center, Giza, Egypt, during two successive seasons (2021/2022 and 2022/2023). The study focused on Iris tingitana cv. Wedgewood to prolong the flowering season and improve flower quality.

Treatments and Application: The experiment evaluated the individual and combined effects of different irrigation intervals (5, 10, and 15 days after sowing - DAS) and various fertilizers applied to the bulbs. The fertilizers used were Kristalon at 2 g/pot, Phosphorein at 5 g/pot, and Nitrobine at 5 g/pot. These fertilizers were applied as soil dressings and were sourced from the Agriculture Research Center. The applications were performed three times at 30-day intervals starting from September 15th at 9 A.M. during both seasons.

Plant Materials: Uniformly sized mother bulbs of Iris (8-9 cm in circumference) were selected for planting on May 15th of both seasons. Each bulb was planted at a depth of 5-6 cm in PVC pots (50 cm in diameter) filled with a growing medium composed of sand, clay, and compost in a 2:1:1 ratio by volume. The chemical characteristics of the growing medium are shown in Table 1.

Experimental description: In both seasons, the bulbs were harvested on May 15th. After cleaning and inspection, bulbs with a diameter of 8-9 cm were selected and stored at room temperature (26-28 ± 3 °C) from May until October. One month after planting (October 15th), the bulbs were divided into three groups corresponding to the irrigation interval treatments (5, 10, and 15 DAS). Each group was further divided into four sets to investigate the effects of different soil amendments: Kristalon alone, Kristalon + Phosphorein, Kristalon + Nitrobine, and untreated control. Regular agricultural practices such as weeding and watering were performed as needed throughout the experiment.

Biofertilizers: Phosphorein and nitrobine were the two biofertilizers used. Two non-symbiotic nitrogen-fixing bacteria are present in Nitrobine, *Azospirillum barasilense* and *Azotobacter chroococcum*, which are found in vermiculite, peat moss, and plant charcoal, respectively. The growing media in each pot received three equal amounts of five grams of biofertilizer. The first dosage was applied before bulb planting; the second and third doses were applied one month later, before blooming at 9 AM, beginning on September 15th as a part of routine care in both seasons. The Department of Microbiology of the Soil, Water, and Environment Research Institute, ARC, Giza, Egypt, graciously provided the bacteria preparations.

Table 2. Chemical analysis of the used compost.

Parameter	Value
pH	6.54
E.C (ds/m)	1.23
O.M (%)	12.90
O.C (%)	7.23
C/N ratio	12.25
N %	0.59
P%	0.22
K%	1.76

Chemical fertilizer: The kristalon analysis: N $_2$0 %, P_2O_5 20 %, K_2O 20 %; EC= 0.9 dS/m. Throughout the growing season, kristalon was applied to the soil at 2.0 g/pot/ three times monthly. After two weeks of planting bulbs, the first addition was applied. The control treatments were without chemical and biofertilizer inoculation.

Experimental layout: The design of the experiment was planned to provide a factorial experiment in randomized complete blocks. The study contained 12 treatments (3 irrigation intervals x 4 rates of fertilization) with three replicates. The treatments (biofertilizer and mineral) were the main plots, and the irrigation interval treatments were the subplots. In each replicate, there were 5 pots. On May 30th the study was finished during the two seasons.

Morphological measurements: During the growth of Iris plants, the following morphological determinations were performed: Plant height (cm) and number of leaves/plant at the flowering stage. The following flowering characteristics were measured during each growing season: number of days from the date of planting to flowering (days), fresh weight of flowers per plant (g), tspike stem length (cm), and spike diameter (mm) flowering date, spike stem length (cm), and diameter(mm), bulb fresh weight, bulb circumference (cm), bulblet fresh weight (g).

Chemical analysis

During each growing season at the flower bud initiation stage, the following analyses were performed:

Pigments: Chlorophyll a, b, (mg/100 g fresh weight) of the fresh leaves of Iris plants were assessed according to Moran (1982).

Total carbohydrate: In new bulbs, total carbohydrates were determined using the colorimetric method described by Dubois *et al.* (1956).

Macro-nutrients: Chemical analyses of nitrogen, phosphorus, and potassium were conducted in oven-dry leaves (dried at 60 °C for 72 hr) to estimate N, P, and K (%), according to the method of Westerman (1990).

Table 1. Analyses of some physical chemicals and characteristics of the growing media used in the plantation (Page *et al.*, 1982)

Soil type	Particle size distribution (%)				S.P	E.C (ds/m)	pH	Cations (meq/L)				Anions (meq/L)		
	Coarse sand	Fine sand	Silt	Clay				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	SO4--
Sand	89.03	2.05	3.40	5.52	25.00	1.75	7.33	5.11	1.08	5.20	1.34	1.96	7.99	1.78
Clay	7.54	22.28	31.11	39.63	40.00	1.97	7.80	4.96	3.10	10.64	1.09	1.02	1.32	7.45

Texture: Sandy clay

Statistical analysis: Data were arranged and subjected to analysis of variance as a factorial experiment using MSTAT statistical software (1985) and means of treatments were compared by LSD at a 5% level as indicated by Snedecor and Cochran (1980).

Results

Vegetative growth: It is clear from the data (Table 3) that the superiority of growing bulbs was at 10 DAS irrigation intervals that elevated vegetative growth, height and number of leaves per plant at the flowering time followed by 5 and 15 DAS irrigation intervals during both seasons. Treating plants with phosphorein and kristalon achieved the highest increase in vegetative growth height and number of leaves per plant followed by plants treated with nitrobine and kristalon while the least one was noticed for untreated bulbs during both seasons. The interactions among soil additives and irrigation intervals realized the prevalence of growing bulbs at 10 DAS irrigation intervals by applying phosphorin and kristalon. This treatment elevated the height of vegetative growth at the flowering time and number of leaves/plant in both seasons. On the contrary, undesirable effects were recorded on such traits at 15 DAS irrigation intervals. The plant experienced water deficit stress during the 15-day watering interval, which may have contributed to the poor performance. In contrast, the best outcomes of a 10-day irrigation interval interval may be attributed to the suitable water amount, which helped good aeration and proper nutrient uptake. Our study found that biofertilizers, combined with mineral fertilizers, enhanced plant growth by increasing phosphorus availability in soil, potentially boosting nitrogen fixation and increasing vegetative growth.

Flowering: Data on the effect of different irrigation intervals and soil additives on some flowering traits of *I. tingitana* cv. Wedgewood presented in Tables 4 and 5 showed that the interaction between phosphorein, kristalon, and (10 DAS) irrigation intervals recorded the highest values in most treatments. Combining phosphorin and kristalon positively impacts the number of days to flowering and spike stem length compared to control in both seasons. Meanwhile, the second rank for improving these raits was occupied by treating plants with

Table 3. Effect of chemical, bio-fertilizers, irrigation intervals, and their interaction on plant height (cm.) and no. of leaves/ plant of *I. tingitana* cv. Wedgewood in the two seasons (2021-2022 and 2022-2023)

Irrigation (A)	Soil additive (B)									
	Plant height (cm.)					No. of leaves/ plant				
	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B
Season 1										
5	63.12	69.12	74.14	78.25	71.16	6.12	6.21	6.32	6.52	6.29
10	69.11	73.12	76.15	82.12	75.13	6.53	6.71	6.91	7.12	6.82
15	60.2	67.11	70.11	75.11	68.13	5.22	5.42	5.51	6.42	5.64
Mean A	64.14	69.78	73.47	78.49		5.96	6.11	6.25	6.69	
CD (*P*=0.05): A= 2.256 B= 3.45 A×B= 5.763						CD (*P*=0.05): A= 2.256 B= 3.452 A×B= 5.763				
Season 2										
5	65.56	70.9	76.14	79.44	73.01	6.2	6.3	6.5	6.7	6.43
10	68.12	75.14	78.3	83.56	76.28	6.5	6.8	7.1	7.3	6.93
15	62.12	68.1	72.17	76.34	69.68	5.1	5.5	6.4	6.6	5.9
Mean A	65.26	71.39	75.54	79.78		5.93	6.2	6.67	6.87	
CD (*P*=0.05): A= 2.465 B= 3.457 A×B=5.234						CD (*P*=0.05): A= 2.465 B= 3.457 A×B=5.234				

Table 4. Effect of chemical, bio-fertilizers, irrigation intervals, and their interaction on the number of days flowering and Spike stem length of *I. tingitana* cv. Wedgewood in the two seasons (2021-2022 and 2022-2023)

Irrigation (A)	Soil additive (B)									
	Number of days to flowering					Spike stem length (cm)				
	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B
Season 1										
5	142.1	138.6	136.7	135.13	138.13	46.34	53.1	60.12	63.13	55.67
10	139.1	137.2	134.41	132.22	135.73	47.13	57.14	64.87	66.89	59.01
15	145.11	140.5	139.1	137.1	140.45	40.13	51.12	57.14	64.14	53.13
Mean A	142.1	138.77	136.74	134.82		44.53	53.79	60.71	64.72	
CD (*P*=0.05): A= 2.423 B= 3.365 A×B=5.456						CD (*P*=0.05): A= 1.523 B= 1.835 A×B= 3.058				
Season 2										
5	140.91	137.12	138.12	137.61	138.44	47.23	54.23	62.12	66.14	57.43
10	138.12	136.2	135.45	135.45	136.31	48.23	59.9	66.12	68.12	60.59
15	138.12	140.11	139.26	139.26	139.19	42.13	53.12	58.21	66.15	54.9
Mean A	139.05	137.81	137.61	137.61		45.86	55.75	62.15	66.8	
CD (*P*=0.05): A= 2.523 B= 3.876 A×B= 5.244						CD (*P*=0.05): A= 1.725 B= 2.018 A×B= 3.550				

Table 5. Effect of chemical, bio-fertilizers, irrigation intervals, and their interaction on fresh weight of cut spike (g.) and spike stem diameter (mm.) of *I. tingitana* cv. Wedgewood in the two seasons (2021-2022 and 2022-2023)

Irrigation (A)	Soil additive (B)									
	Fresh weight of cut spike (g)					Spike stem diameter (mm)				
	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B
Season 1										
5	24.33	28.11	30.11	36.11	29.67	0.66	0.71	0.73	0.75	0.71
10	27.1	30.14	33.12	39.14	32.38	0.7	0.72	0.75	0.78	0.74
15	23.11	24.67	28.11	29.13	26.26	0.63	0.65	0.68	0.7	0.67
Mean A	24.85	27.64	30.45	34.79		0.66	0.69	0.72	0.74	
	CD (P=0.05): A=1.342 B= 2.128 A×B= 3.568					CD (P=0.05): A= 0.021 B= 0.063 A×B=0.171				
Season 2										
5	27.33	28.11	34.15	36.2	31.45	0.72	0.73	0.76	0.79	0.75
10	29.15	31.5	36.2	39.15	34	0.74	0.77	0.78	0.81	0.78
15	25.14	26.14	29.1	34.12	28.63	0.68	0.71	0.75	0.78	0.73
Mean A	27.21	28.58	33.15	36.49		0.71	0.74	0.76	0.79	
	CD (P=0.05): A= 1.432 B= 2.783 A×B= 3.234					CD (P=0.05): A= 0.043 B= 0.075 A×B= 0.127				

nitrobine and kristalon.

Bulb and bulblets parameters: In our research, the use of biofertilizers in addition to mineral fertilizers resulted in significantly better results on bulb and bulblets parameters. It is evident from data (Tables 6 and 7) that positive effects were detected on the number of bulbs per pot (bulbs yield), fresh weight, and circumference of new bulbs due to applying phosphorin, kristalon, and irrigation interval of 10 DAS as compared to control in both seasons. Meanwhile, plants treated with nitrobine, kristalon, and irrigation interval of 10 DAS attained the second position for some bulbs and bulblets traits of *I. tingitana* cv. Wedgewood.

Chemical constituents of plants: The data in Tables (8, 9 and 10) showed the highest values in most treatments as compared with control in both seasons. The increase in all macro elements in Iris plants may be due to the stimulatory influence of the interaction between phosphorein, kristalon, and 10 DAS irrigation interval on the vegetative growth and flowering as mentioned before.

Discussion

The observed increase in vegetative growth characteristics, such as plant height and the number of leaves, can be attributed to the interaction between phosphorein, kristalon, and the 10 DAS irrigation intervals. The enhanced vegetative growth parameters are likely influenced by the N, P, and K content of Kristalon. Nitrogen is essential for protein formation, contributing to cell enlargement and division, while phosphorus is crucial for energy production in physiological processes, such as protein synthesis via adenosine triphosphate (ATP). Phosphate also activates enzymes, enhancing metabolism and cell formation, and regulates various enzymatic processes in plants. Additionally, potassium plays a significant role in plant metabolism.

Table 6. Effect of chemical, bio-fertilizers, irrigation intervals, and their interaction on number of bulbs and fresh weight of bulbs (g.) of *I. tingitana* cv. Wedgewood in the two seasons (2021-2022 and 2022-2023)

Irrigation (A)	Soil additive (B)									
	Number of bulbs					Fresh weight of bulbs (g.)				
	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B	Control	Kristalon	Kristalon + nitrobine	Kristalon+ phosphorein	Mean B
Season 1										
5	2.17	3.01	3.24	4.20	3.16	4.53	6.25	7.2	8.2	6.55
10	2.3	3.04	3.5	4.50	3.34	5.40	6.50	7.14	8.24	6.82
15	2.13	2.70	3.14	3.09	2.77	4.13	5.14	7.03	8.11	6.10
Mean A		2.92	3.29	3.93		4.69	5.96	7.12	8.18	
CD (P=0.05): A= 1.465 B= 1.234 A×B=3.567						CD (P=0.05): A= 1.440 B= 2.258 A×B=0 3.515				
Season 2										
5	2.35	3.78	3.60	4.62	3.59	6.10	6.30	7.25	8.31	6.99
10	3.15	4.18	4.12	4.69	4.04	6.22	6.53	7.31	8.34	7.10
15	2.25	2.88	3.55	3.52	3.05	5.40	6.2	7.14	8.15	6.72
Mean A	2.58	3.61	3.76	4.28		5.91	6.34	7.23	8.27	
CD (P=0.05): A= 1.404 B= 1.811 A×B= 3.245						CD (P=0.05): A= 1.525 B= 2.334 A×B= 3.420				

Table 7. Effect of chemical, bio-fertilizers, irrigation intervals, and their interaction on bulb circumference (cm.) and fresh weight of bulblet (g.) of *I. tingitana* cv. Wedgewood in the two seasons (2021-2022 and 2022-2023)

Irrigation (A)	Soil additive (B)									
	Bulb circumference (cm)					Fresh weight of bulblet (g.)				
	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B
Season 1										
5	5.14	7.14	7.35	7.43	6.77	0.73	1.56	1.78	1.81	1.47
10	5.61	7.2	7.45	7.55	6.95	0.79	1.89	1.85	1.89	1.61
15	5	6.67	7.1	7	6.44	0.7	1.38	1.67	1.77	1.38
Mean A	5.25	7	7.3	7.33		0.74	1.61	1.77	1.82	
	CD (*P*=0.05): A= 0.214 B= 0.577 A×B= 1.278					CD (*P*=0.05): A= 1.440 B= 2.258 A×B=0 3.515				
Season 2										
5	5.1	7.2	7.39	7.46	6.79	0.73	1.51	1.75	1.87	1.47
10	5.5	7.25	7.35	7.58	6.92	0.79	1.67	1.89	1.92	1.57
15	5.16	6.69	7.19	7	6.51	0.84	1.9	1.93	1.95	1.66
Mean A	5.25	7.05	7.31	7.35		0.79	1.69	1.86	1.91	
	CD (*P*=0.05): A= 0.299 B= 0.612 A×B= 1.42					CD (*P*=0.05): A= 0.65B= 0.563A×B= 1.127				

Table 8. Effect of chemical, bio-fertilizers, irrigation intervals, and their interaction on chlorophyll a and b (mg/g f.w.) of *I. tingitana* cv. Wedgewood in the two seasons (2021-2022 and 2022-2023)

Irrigation (A)	Soil additive (B)									
	Chlorophyll a (mg/g f.w.)					Chlorophyll b (mg/g f.w.)				
	Control	Kristalon	Kristalon + nitrobine	Kristalon+ phosphorein	Mean B	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B
Season 1										
5	0.71	0.73	0.75	0.78	0.74	0.45	0.46	0.47	0.49	0.47
10	0.74	0.75	0.79	0.82	0.78	0.46	0.48	0.5	0.52	0.49
15	0.75	0.76	0.84	0.85	0.8	0.4	0.43	0.45	0.46	0.44
Mean A	0.73	0.75	0.79	0.82		0.44	0.46	0.47	0.49	
	CD (*P*=0.05): A= 0.135 B= 0.252 A×B= 0.309					CD (*P*=0.05): A= 0.339 B= 0.294 A×B= 0.588				
Season 2										
5	0.74	0.75	0.77	0.82	0.77	0.43	0.48	0.49	0.51	0.48
10	0.75	0.83	0.84	0.86	0.82	0.45	0.49	0.52	0.56	0.51
15	0.78	0.86	0.87	0.89	0.85	0.44	0.45	0.47	0.48	0.46
Mean A	0.76	0.81	0.83	0.86		0.44	0.47	0.49	0.52	
	CD (*P*=0.05): A= 0.150 B= 0.278 A×B= 0.351					CD (*P*=0.05): A= 0.238 B= 0.243 A×B= 0.411				

Table 9. Effect of chemical, bio-fertilizers, irrigation intervals, and their interaction on nitrogen % and phosphorus (%) of *I. tingitana* cv. Wedgewood in the two seasons (2021-2022 and 2022-2023)

Irrigation (A)	Soil additive (B)									
	Nitrogen %					Phosphorus (%)				
	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B	Control	Kristalon	Kristalon+ nitrobine	Kristalon+ phosphorein	Mean B
Season 1										
5	1.67	1.86	1.98	2.1	1.9	0.27	0.32	0.34	0.36	0.32
10	1.8	1.92	2.06	2.15	1.98	0.28	0.33	0.34	0.37	0.33
15	1.56	1.79	1.87	1.96	1.8	0.25	0.27	0.29	0.32	0.28
Mean A	1.68	1.86	1.97	2.07		0.27	0.31	0.32	0.35	
CD (*P*=0.05): A= 0.0318 B= 0.0446 A×B= 0.0789						CD (*P*=0.05): A= 0.0328 B= 0.0504 A×B= 0.0734				
Season 2										
5	1.69	1.87	1.93	2.14	1.91	0.26	0.31	0.33	0.36	0.32
10	1.82	1.94	2.04	2.16	1.99	0.29	0.34	0.35	0.38	0.34
15	1.58	1.82	1.89	2	1.82	0.26	0.29	0.3	0.34	0.3
Mean A	1.7	1.88	1.95	2.1		0.28	0.31	0.33	0.36	
CD (*P*=0.05): A= 0.0350 B= 0.071 A×B= 0.0734						CD (*P*=0.05): A= 0.0398 B= 0.0561 A×B= 0.0845				

Table 10. Effect of chemical, bio-fertilizers, irrigation intervals, and their interaction on potassium % and total carbohydrates (%) of *I. tingitana* cv. Wedgewood in the two seasons (2021-2022 and 2022-2023)

Irrigation (A)	Soil additive (B)									
	Potassium %					Total carbohydrates (%)				
	Control	Kristalon	Kristalon + nitrobine	Kristalon+ phosphorein	Mean B	Control	Kristalon	Kristalon + nitrobine	Kristalon+ phosphorein	Mean B
Season 1										
5	1.17	1.41	1.64	2.22	1.61	18.1	18.43	19.98	20.78	19.32
10	1.2	1.43	1.74	2.14	1.63	18.56	19.76	20.14	20.94	19.85
15	1.15	1.38	1.39	2.11	1.51	16.08	18.2	19.15	20.64	18.52
Mean A	1.17	1.41	1.59	2.16		17.58	18.8	19.76	20.79	
CD (P=0.05): A= 0.125 B= 0.298 A×B= 0.322						CD (P=0.05): A= 1.799 B= 2.767 A×B= 4.025				
Season 2										
5	1.53	1.59	1.68	2.24	1.76	18.33	19.1	20.15	20.66	19.56
10	1.67	1.56	1.78	2.36	1.84	18.41	19.43	20.5	20.7	19.76
15	1.26	1.41	1.45	2.15	1.57	17.17	18.3	19.45	20.66	18.9
Mean A	1.49	1.52	1.64	2.25		17.97	18.94	20.03	20.67	
CD (P=0.05): A= 0.189 B= 0.309 A×B= 0.453						CD (P=0.05): A= 1.908 B= 2.891 A×B= 4.792				

The combination of biofertilizers and chemical fertilizers has shown positive effects on plant growth, primarily by increasing phosphorus availability in the soil and potentially enhancing total nitrogen fixation. Phosphate-solubilizing (PS) bacteria support plant growth by improving the efficiency of biological nitrogen fixation, which increases the availability of other trace elements, such as iron and zinc, and produces phytohormones. These results corroborate the findings of Bostan *et al.* (2014) on Amaryllis, Mansour *et al.* (2015) on Gladiolus, and Sathyanarayana *et al.* (2017) on flower crops.

The study suggests that biochemical fertilizers, particularly bacterial inoculation, can improve flowering parameters such as spike stem length, fresh weight, and spike stem diameter by increasing soil phosphorus (P) availability and overall nutrient availability. Microorganisms like Bacillus megatherium and Azotobacter enhance rhizosphere microbiological activity, contributing to mineral solubilization and increasing the availability of scarce nutrients. Additionally, a 10-day irrigation interval yields good results. These findings are consistent with those of El-Naggar *et al.* (2010), El-Khawaga and Maklad (2013), Bostan *et al.* (2014), Mansour *et al.* (2015), and Hassan *et al.* (2016).

Regarding bulb and bulblet parameters, the interaction between Phosphorein and Kristalon likely explains the results. The biofertilizer Phosphorein contains Bacillus megatherium bacteria, which are highly effective in converting tricalcium phosphate into monophosphate, making it more accessible to plants. These bacteria multiply rapidly and spread in the root zone, providing beneficial phosphorus necessary for various stages of plant growth, thus increasing the number of bulbs. The increase in bulb yield is in line with the findings of Muraleedharan *et al.* (2010) and Atwa *et al.* (2023). This is further supported by recent research showing similar results (Lahiji *et al.*, 2012; Bostan *et al.*, 2014; Ahmad *et al.*, 2014; Sathyanarayana *et al.*, 2017).

The chemical constituents in leaves, such as chlorophyll a and b, are affected by the interaction between Phosphorein, Kristalon, and the 10 DAS irrigation interval. These findings are due to the use of biochemical fertilizers, which play a crucial role in the production of auxins that increase cell division and pigment content in leaves. These results are in good harmony with those of Gomaa *et al.* (2018) on Hibiscus sabdariffa L. Current research on iris plants revealed that all macro elements may be stimulated by the applied Phosphorein, Kristalon, and 10 DAS irrigation interval on vegetative growth and flowering, as mentioned earlier. Abdel-Said *et al.* (2018) demonstrated that in both seasons, all biofertilizer treatments improved nitrogen (N) buildup in leaves relative to the control. Additionally, Abdel-Said *et al.* (2019) found that Lilium longiflorum Thunb. with irrigation intervals of 10 and 12 DAS reported the best N, P, and K percentages ever. Similarly, phosphorus concentration in new bulbs demonstrated the effectiveness of the 10 DAS irrigation interval across both seasons, while potassium buildup also increased with the same treatment. New bulbs in both seasons had the highest levels of N, P, and K when Phosphorein, Kristalon, and the 10 DAS irrigation intervals were used. Nitrobine, Kristalon, and the 10 DAS irrigation interval were the second most effective treatment. Several researchers have confirmed the frequency of bio and chemical fertilizers for increasing N% in various plant species. The outcomes of N%, P%, K%, and total carbohydrates in new bulbs are consistent with those of Abdel-Said *et al.* (2019), Fatmi (2023), and Sarmah and Sarma (2023).

Based on the results, it is recommended to irrigate Iris tingitana cv. Wedgewood at 10-day intervals (DAS) and apply Phosphorein and Kristalon as soil drenches six times, starting two weeks after bulb sprouting until the beginning of flowering. This approach will enhance vegetative growth, flowering parameters, bulb and bulblet production, and the chemical composition of vegetative growth and new bulbs. As a second-best option, applying Nitrobine and Kristalon as a soil drench at the same 10 DAS interval, six times from two weeks after bulb sprouting until flowering, is also advised to achieve optimal plant traits.

Acknowledgments

The authors extend their gratitude 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 ongoing assistance, guidance, and manuscript review.

References

Abdel-said, Z.H.R., O.N.K. Emam and A. Nabih, 2018. Improving, growth, flowering, bulbs and bulblets production, and chemical constituents of *I. tingitana* cv. Wedgewood by using different types and levels of fertilization treatments. *Middle*. *East J. Agric. Res*., 7(4): 1583-1591.

Abdel-Said, Z.H.R., W.M. Bazaraa and A. Nabih, 2019. Effect of amino acid (threonine), irrigation levels and their interaction on growth, flowering, bulbs productivity and chemical constituents of *Lilium longiflorum*, Thunb. plant, *Middle East J. Agr. Res*., 8(1): 153-166.

Ahmad, A., M.Tahir, H.Rashid, B.Ajmal, R.Sajjad & A.Adeel, 2014. Investigation of biofertilizers influence on vegetative growth, flower quality, bulb yield and nutrient uptake in gladiolus (*Gladiolus grandiflorus* L.). *J. Plant, Animal Int. Environ. Sci.*, 4(1): 94-99.

Atwa, I.D., S.A.Soliman, H.M.El-Fikey and M.M.Abdel-Wahab, 2023. Natural extracts elevated drought resistance in *I. tingitana* plant. *J. Appl. Hortic.,* 25(1): 54-59.

Bostan, N., M.Sajid, F. Rabi and M.Munir, 2014. Effects of growing media and irrigation intervals on flower production of amaryllis (*Amaryllis belladonna*). *J. Biol. Agric. Healthc*., 4(6): 38-44.

Dubois, M. and K.A.Gilles, JK Hamilton, PA Rebers, and F. Smith, 1956. *Anal. Chem*., *28*, p.350.

El-Khawaga, A. S., and M.F.Maklad, 2013. Effect of combination between bio and chemical fertilization on vegetative growth, yield and quality of Valencia orange fruits. *Hort. Sci. J. Suez Canal Univ.,* 1: 269-279.

El-Naggar, A. H., 2010. Effect of biofertilizer, organic compost and mineral fertilizers on the growth, flowering and bulbs production of *Narcissus tazetta*, L. *J Agric. Env. Sci. Alex. Univ., Egypt*, 9(1): 24-52.

El-Wahab, M. A. A., 2013. Effect of biofertilizer and chemical fertilization on growth and active constituents of *Origanum syriacum* var. Sinaicum (Boiss.). plant under Saint Katherine condition. *Res. J. Agric. Biol. Sci.*, 9(5): 182-190.

Fatmi, U., 2023. Effect of bio-fertilizers on growth, flowering, yield and quality of chrysanthemum (*Dendranthema grandiflora* T.) cv. Snowball under open field conditions of Prayagraj, India. *Inter. J. Plant & Soil Sci*., *35*(18): 2030-2036.

Fayaz, K., F.U.Khan, I.T. Nazki, M.U. Nisa, P. Verty and V.K. Singh, 2018. Effect of integrated nutrient application on yield and bulb production character in Tulip (*Tulipa gesneriana* L.) cv.“Red Beauty”. *Int. J. Curr. Microbiol. App. Sci.*, 190-195.

Ghatas, Y. A. E. F., and Y.F.Y.Mohamed, 2020. Influence of some phosphorus sources and biofertilizers (EM and phosphorein) on vegetative growth, fixed oil productivity and chemical constituents of *Oenothera biennis* L. plant. *Sci. J. Flowers Ornamental Plants*, *7*(3): 247-268.

Gomaa, A. O., A.S.M.Youssef, Y.F.Y.Mohamed and M.S.AbdAllah, 2018. Effect of some fertilization treatments on growth, productivity and chemical constituents of roselle (*Hibiscus sabdariffa* L.). plants. *Sci. J. Flowers Ornamental Plants*, *5*(2): 171-193.

Hassan, M. R., A.El-NaggarM.N., Nasr and M.B. El-Deeb, 2016. Effect of mineral, bio-fertilizertion and growing media on growth , flowering and corms production of *Gladiolus grandiflorus* Cv.” White prosperity” plant . *Sci. J. Flowers Ornamental Plants*, 3(1): 45-70.

Lahiji, M. F., A.R.Midani and S.Chaeikar, 2012. Effect of irrigation intervals and different mulches on some traits of Gladiolus cv. Rose supreme. *Seed Plant Prod. J.,* 28(2): 239-248.

Mansour, H. A., M.M.M.Hussein, S.A. Gomaa and N.F.A. El-Ghazaly , 2015. Response of *Gladiolus grandiflorns* cv. Peter Pears to different drip irrigation levels and Kristalon treatments. *J. Biol. Chem. Environ. Sci.*, 10(2): 417-433.

Mohamed, Y. F. Y. and Y.A.A.Ghatas, 2016. Effect of mineral, biofertilizer (EM) and zeolite on growth, flowering, yield and composition of volatile oil of Viola odorata L. plants. *J. Hortic. Sci. Ornamental Plants*, 8(3): 140-148.

Moran, R., 1982. Formulae for determination of chlorophyllous pigments extracted with N, N-dimethylformamide. *Plant Physiol*., 69(6): 1376-1381.

MSTAT Computer Program, 1985. Software program for design, management and analysis experimental (Version 4.0): Michigan State Univ.

Muraleedharan, H., S. Seshadri and K. Perumal, 2010. Biofertilizer (phosphobacteria). Shri AMM Murugappa Chettiar Research Centre. Taramani, Chennal-600113.

Page, A.L, R.H. Miller and D.R. Keeney, 1982. Methods of Soil Analysis. Am. Soc. Agron. Madison, Wisconsin, USA.

Sathyanarayana, E., S.Patil and S.L.Chawla, 2017. A review-bio-fertilizers role and use in flower crops. *Trends Biosci.*, 10(20): 3734-3736.

Singh, V., K.C.Sharma and H.R. Sharma, 2017. Effect of bio-inoculants and graded level of fertilizers on nutrient uptake in garlic. *Int. J. Curr. Microbiol. App. Sci.*, 6(5): 1200-1209.

Snedecor, G.W. and W.G. Cochran, 1980. Statistical methods 7th Ed Iowa State Univ. Press, Ames, Iowa, USA.

Westerman, R.L. 1990. Soil Testing and Plant Analysis. (3rd ed) Soil Science Society of America, Inc. Madison Wisconsin, USA.

Wilson, C.A. 2011. Subgeneric classification in Iris re-examined using chloroplast sequence data. *Taxon*, 60(1): 27-35.

Received: June, 2024; Revised: July, 2024; Accepted: July, 2024